# Combining Measurement Tools to Understand the Context of Children's Indoor and Outdoor Leisure-Time Physical Activity

Matthew Pearce

Thesis submitted for the degree of Doctor of Philosophy

The University of Edinburgh

2015

## Declaration

I, Matthew Pearce, certify:

(a) that the thesis has been composed by me, and

(b) either that the work is my own, or, where I have been a member of a research group, that I have made a substantial contribution to the work, such contribution being clearly indicated, and

(c) that the work has not been submitted for any other degree or professional qualification except as specified.

Signed: ……………………………………………………………………………….

Date: ………………………………………………………………………………

## Acknowledgements

I would like to thank a number of people who have assisted me in different ways whilst working to complete this thesis. Firstly I would like to thank my supervisors, Tony Turner, Pete Allison and Dave Saunders. They have contributed considerable time to provide feedback on my research and guide my academic development. Their range of expertise and experience has proven invaluable during the different stages of my studies and they have also supported my progress in other academic areas such as teaching. I have learned much from each of them and I am very grateful for all their help.

I would also like to acknowledge the input and support of the members of the Physical Activity for Health Research Centre. The opportunity to present my work at seminars and benefit from a research culture with a physical activity focus has been hugely rewarding. Of the group members, I would particularly like to thank Sam Fawkner and Ailsa Niven who provided constructive criticism at my progression board and second year review.

I must also say thank you to Angie Page, Tom Griffin and Ashley Cooper at the University of Bristol. In addition to collaborating on a study that made use of data from the Personal and Environmental Associations with Children's Health (PEACH) project, Ashley assisted by providing script for matching of GPS and accelerometer data used in other parts of the thesis, whilst Tom was extremely patient and helpful when providing guidance on statistical analyses. The efforts of the team who originally collected the PEACH data between 2006 and 2008 must also be recognised.

This thesis would not have been possible without the efforts of all the teachers, school staff and parents who have kindly facilitated data collection in Edinburgh, and a special thank you goes out to all the participants who gave their time and effort.

Finally I would like to recognise my friends and family for their considerable backing over the past few years.

## Abstract

This aim of this thesis evolved following a review of the literature investigating the factors which influence children's participation in outdoor play. The review was conducted in light of theory recommending that when seeking to promote physical activity, considering context-specific behaviours and behaviour-specific determinants can enhance the effectiveness of interventions. An initial focus on outdoor play was warranted given the capacity for promotion of physical activity during leisure-time, concerns that children's independent time outdoors is becoming increasingly restricted, and limited research focus on this domain of physical activity. The synthesised quantitative and qualitative evidence indicated that independent mobility, parental perceptions of safety and the availability of other children to play with were important factors related to outdoor play. However, the review also demonstrated that current understanding of how, where and with whom children spend their leisure-time is limited, and that traditional notions of children's outdoor time may need to be re-evaluated. These deficiencies were in part due to the complexity of defining and measuring children's outdoor play. The contributions of different indoor and outdoor leisure-time contexts towards total daily moderate to vigorous physical activity (MVPA) was identified as a particular knowledge gap. The aim of this thesis was therefore to develop greater understanding of the indoor and outdoor contexts of children's leisure-time physical activity.

A novel approach to context-specific physical activity research was devised. This method incorporated use of accelerometry to record physical activity intensity with high resolution, Global Positions System (GPS) receivers to automatically record indoor or outdoor location, and diary data to provide complementary contextual detail. Rather than utilise a domain label such as outdoor play, this method sought to combine measurement tools to not only objectively record physical activity intensity, but also build a picture of the context of this activity using combinations of contextual attributes. Children at the transition between primary and secondary school were the focus of the research due to the changes in independence which occur at approximately this age (10-13 years). The research consisted of three studies presented across three chapters.

Chapter Five used data collected between 2006 and 2008 from children aged 10–11 years from Bristol involved in the Personal and Environmental Associations with Children's Health (PEACH) project. Given the association of outdoor play with independent mobility and the availability of other children, the chapter quantified who children spent their time with when indoors or outdoors after school, and measured associations with MVPA. Using a newer GPS receiver, Chapter Six aimed to assess the feasibility of using GPS data to differentiate indoor and outdoor location, and establish a cut-point for use in free-living individuals. Chapter Seven then used this GPS method in combination with accelerometry and diary data provided by children aged 11-13 years from Edinburgh. Owing to concerns that children's unstructured outdoor time is restricted by parents in favour of adult organised sport and clubs, the chapter aimed to record the profile of children's physical activity. This was achieved by recording whether indoor and outdoor leisure-time physical activity was structured or unstructured, and exploring relationships between periods spent in these contexts and total daily MVPA.

Chapter Six demonstrated that using the signal-to-noise ratio from GPS data is an accurate tool for differentiating indoor and outdoor location, with 96.8% of all ten-second epochs correctly classified. Together the findings of Chapters Five and Seven suggest that children obtain their physical activity in multiple contexts and that no single context appears to fulfil the recommendation of 60 minutes of MVPA per day. Chapter Five showed that children spent most of the after school period with parents or alone, especially when indoors. However when participants were outdoors with other children, multivariate regression analyses indicated that these periods were most strongly associated with MVPA. Complementing these findings, Chapter Seven revealed that in a relatively active and affluent sample, participants accumulated most of their MVPA in school-time or unstructured leisure-time contexts (both indoors and outdoors). The results revealed that these active children spent more than one hour in unstructured outdoor leisure-time contexts each day. However, associations with MVPA were weaker than expected, and whilst being outdoors was favourable compared to being indoors, it was apparent that there is scope to maximise MVPA further when children are outdoors. The median contributions of structured leisure-time contexts to daily MVPA were minimal regardless of indoor or outdoor location.

Deconstructing leisure-time according to contextual attributes recorded by a combination of measurement tools proved to be an informative approach for understanding variation in children's MVPA. Taken together the findings of the thesis indicate potential for leisure-time to contribute greater volumes of MVPA. The results emphasise the importance of children being outdoors, the value of unstructured forms of physical activity and the necessity for children to spend time with their peers. It is clear from these studies that indoor time is also a vital source of MVPA. The work presented in this thesis makes a valuable contribution to our understanding of how children spend their leisure-time and how this relates to physical activity. Further research is required to explore the many other contextual attributes of children's leisure-time, so that indoor and outdoor environments can be manipulated as part of multi-component interventions that promote physical activity as effectively as possible.

## List of tables

## List of figures

## Table of contents

# Chapter One

# Introduction

It is widely acknowledged that physical activity during childhood confers beneficial effects on musculoskeletal health, mental health, adiposity and cardiovascular disease risk factors (Janssen & Leblanc, 2010; Strong et al., 2005). Unfortunately, like many adults, most contemporary children do not accrue enough physical activity (Currie et al., 2011; Riddoch et al., 2004), and the burden of this inactivity is unacceptably high (Lee et al., 2012). The World Health Organization identifies physical inactivity as the eighth leading risk factor for global mortality (Lim et al., 2012), while in the UK, inactivity has a major preventable economic impact on the National Health Service (Scarborough et al., 2011). Developing strategies to promote physical activity in paediatric populations is a major public health priority.

To date, most interventions to promote children's physical activity have been ineffective (Atkin, Gorely, Biddle, Cavill, & Foster, 2011; Cale & Harris, 2006; Dobbins, Husson, DeCorby, & LaRocca, 2013). To develop interventions that can have a sustained positive impact on activity levels, it is necessary to better understand the causes of physical activity and why some children are more active than others (Sallis, Owen, & Fotheringham, 2000a). Many factors operating at and between levels of influence (e.g. intrapersonal, socio-cultural, physical environmental and policy) are thought to be working (Sallis, Owen, & Fisher, 2008). Of particular interest is how these determinants vary between different types and contexts of physical activity (Bauman et al., 2012).

One domain that has been implicated in children's current low levels of physical activity is outdoor play. Today's children are thought to play outside less often, spend less time outdoors and are more restricted in their movement outside the home (Hillman, Adams, & Whitelegg, 1990; Pooley, Turnbull, & Adams, 2005). In a poll conducted by the National Trust, 1000 parents and grandparents reported that 54% of children spend less than one hour outside each day, compared to an average of more than 2.5 hours outdoors in their own youth (Singh, 2014, July 11). Parents are increasingly restricting children's independent mobility (Hillman, 2006; Hjorthol & Fyhri, 2009), and in a single generation since the 1970s, it is reported that children's radius of activity around their home, where they could roam unsupervised, reduced by 90% (Gaster, 1991). Nine out of ten children have never played conkers, built a raft or climbed a tree, leading some to question whether traditional outdoor activities may become extinct (Active Healthy Kids Canada, 2012; Singh, 2014, July 11). Simultaneously, children are being lured indoors by attractive screen-based sedentary behaviours (Atkin, Gorely, Biddle, Marshall, & Cameron, 2008). For example, in 2011, children were reported to watch just over 17 hours of television per week, up 12% from 2007 (Ofcom, 2012).

Overprotective parenting, a focus on sport and ever-present technology mean that children are driven into highly controlled environments, with little chance to explore, run around and interact with peers on their own terms (Active Healthy Kids Canada, 2012). Limited time outdoors and restricted independent mobility deny children an important source of physical activity (Cleland et al., 2008; Cooper et al., 2010; Prezza et al., 2001; Wen, Kite, Merom, & Rissel, 2009) and its protective effects on physical and mental health, but this also has other detrimental effects such as declining emotional resilience and inability to assess risk (Moss, 2012).

Whilst UK Government departments have committed substantial sums to promoting children's sport (Department of Health, 2012; Sport England, 2012), informal and unstructured activities such as outdoor play have received relatively little attention. This erosion of children's freedom to venture outdoors to play is concerning, and represents an important target to increase children's physical activity levels, not least because participation in outdoor play is free and does not require expensive equipment. At present outdoor play is not well understood, and identifying the determinants of this behaviour is an important step towards shaping effective behaviour-specific interventions. Understanding the variety of children's outdoor play experiences and why some children participate more than others are critical knowledge gaps that require investigation.

## 1.1 Initial Aim of the Thesis

The initial aim of this thesis is to develop greater understanding of the potential role of outdoor play as an intervention target to increase children's physical activity levels.

## 1.2 Thesis Structure

Including this introductory chapter, the thesis has a total of eight chapters.

**Chapter Two** introduces the role physical activity plays for children's health, explains the use of social-ecological models to understand physical activity behaviours and describes patterns of children's physical activity. Chapter Two concludes by outlining the need for context-specific interventions, and the need to better understand children's outdoor play as a potential intervention target.

**Chapter Three** reviews the quantitative and qualitative literature aiming to investigate the intrapersonal, social-cultural and physical-environmental factors related to outdoor play. Knowledge gaps and weaknesses in understanding are highlighted.

**Chapter Four** uses the findings of this review to describe refinements to the aim of the research and the need to further explore the indoor and outdoor contexts of children's leisure-time. Three research questions are set out (see below) and the methodological approach to answer these questions is explained and justified.

1. Who do children spend their indoor and outdoor leisure-time with, and how does time spent in these contexts relate to after school moderate to vigorous physical activity (MVPA)?
2. Is it possible to use GPS signal-to-noise ratio data to discriminate indoor and outdoor physical activity locations?
3. Is children's indoor and outdoor leisure-time structured or unstructured, and how does time spent in these contexts relate total daily MVPA?

**Chapter Five** addresses the first research question. It uses previously collected data from the Personal and Environmental Associations with Children's Health (PEACH) project to explore who children spend their indoor and outdoor time with after school and how this relates to MVPA.

**Chapter Six** addresses the second research question. It describes a study which develops a method to distinguish indoor and outdoor location using GPS receiver data.

**Chapter Seven** addresses the third research question. It reports new data collected from schools in the City of Edinburgh. The study investigates the contributions of structured and unstructured leisure-time occurring indoors and outdoors towards total daily MVPA.

**Chapter Eight** presents an overview of the research and highlights the main findings and contributions of the thesis. Finally the limitations of the work as a whole are discussed and recommendations are made for future research.

## 1.3 Dissemination

### 1.3.1 Publications.

Pearce, M., Page, A.S., Griffin, T.P. and Cooper, A.R. (2014). Who children spend time with after school: associations with objectively recorded indoor and outdoor physical activity. *International Journal of Behavioral Nutrition and Physical Activity*, 11:45.

### 1.3.2 Presentations.

Pearce, M., Turner, T., Allison, P. and Saunders, D. (2013). Inside or outside? Examining the use of GPS data to differentiate physical activity location. *Poster presentation at 2013 Annual Meeting of the International Society for Behavioral Nutrition and Physical Activity (ISBNPA)*, *Ghent, NL.*

# Chapter Two
# Background

## 2.1 Introduction

Chapter Two begins by providing an introduction to physical activity for health, including an explanation of the requirement for physical activity interventions targeting child populations. Next, methods for measuring children's physical activity are overviewed. This is followed by a description of key theoretical concepts underpinning current understanding of children's physical activity and subsequent intervention design. The chapter concludes with an overview of the patterns of children's physical activity. In doing so, this chapter provides the rationale for the research that follows.

## 2.2 Physical Activity for Health

The prevention and treatment of disease requires an understanding of the causes of ill-health. Many diseases and risk factors have a behavioural component to their aetiology, for example smoking, hand washing, and alcohol consumption can be linked to health outcomes. Behavioural epidemiology is the branch of public health research which aims to understand and influence health behaviours in order to prevent disease and promote health on a population level (Sallis et al., 2000a). To guide this task, the behavioural epidemiological framework details five research phases culminating in evidence based health interventions (Sallis & Owen, 1999). The five phases as described by Sallis & Owen (1999) are: 1) establish links between behaviour and health; 2) develop methods for measuring the behaviour; 3) identify factors that influence behaviour; 4) evaluate interventions to change behaviour; and 5) translate research into practice.

The present thesis is concerned with applying this framework to children's physical activity. In other words, the work presented in this thesis sits within the overall target of health promotion and disease prevention by increasing childhood physical activity levels. Phase 1 of the framework establishes links between behaviours and health. However, demonstrating links between physical activity and positive health outcomes is insufficient to justify interventions. Public health action and funding should be prioritised for behaviours that are both risky (i.e. clearly linked to health problems) and prevalent (Kohl et al., 2012). Therefore, the following introductory sections demonstrate: 1) the public health importance of physical activity and the burden of inactivity; and 2) the prevalence of inactivity in the population.

### 2.2.1 Defining physical activity.

The term physical activity defines any bodily movement caused by skeletal muscle resulting in energy expenditure (Caspersen, Powell, & Christenson, 1985). Physical activity energy expenditure is often quantified using kilocalories (kcal), equivalent to 4.2 kilojoules (kJ). The rate of energy expenditure or 'intensity' continuum (see Figure 2.1) ranges from behaviours with very low energy expenditure, such as sleep, to vigorous activities with high energy expenditure such as sprinting (Tremblay, Colley, Saunders, Healy, & Owen, 2010).

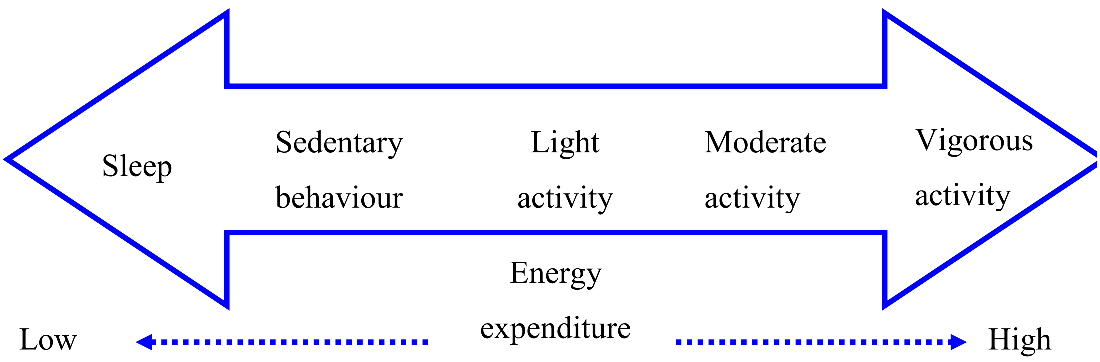



Figure 2.1 *The continuum of human movement and energy expenditure.*
*Source*: British Heart Foundation National Centre (2012).

The energy expenditure or metabolic cost of movement can be expressed using the metabolic equivalent or MET (Ainsworth et al., 2011). One MET is equal to an individual's resting metabolic rate or energy expenditure. Individual behaviours are assigned a MET value representing their energy cost relative to this resting value. For example, a MET value of 2.0 represents a doubling of the resting rate of energy expenditure and would be indicative of light physical activity. A full compendium of behaviours and their associated MET scores was originally published in 1993

(Ainsworth et al., 1993) and has recently been updated (Ainsworth et al., 2011) to include 821 activities ranging from sleep (1.0 MET) to running at 14.0 mph (23.0 METs). The MET system is often used to classify different types of activity according to absolute intensity. For example, behaviours with a MET score between 1.0 and 1.5 may be considered sedentary, while the lower limit for moderate intensity physical activity is said to start at 3.0 METs (Pate et al., 1995), although this is contentious.

Physical activity is the broad label that encompasses all movement of at least light intensity, and extends to movement of moderate and vigorous intensity. It includes housework, walking, cycling for transport, load-carrying, using stairs and many other undertakings of daily life. Physical activity is not interchangeable with terms such as 'sport' or 'exercise', although these too are important sub-categories of physical activity. Sedentary behaviours are those at the lower end of the energy expenditure spectrum, of insufficient intensity to be classified as light physical activity. Sedentary behaviour is not just the absence of physical activity but a separate behaviour in its own right (Tremblay et al., 2010).

The product of the intensity, duration and frequency of physical activity defines the total volume during a given time period. Summarising the volume of physical activity according to categories such as type or location provides a description of where and in what way physical activity occurs. The complexity and breadth of physical activity behaviour means that there are many methods of classification, however recording the total amount of light, moderate and vigorous intensity physical activity is an especially valuable system of classification, particularly in the context of physical activity for health.

### 2.2.2 Links between physical activity and health.

The body of evidence indicating links between physical activity and health is strong and expanding. Physical activity can prevent or help manage more than 20 chronic conditions including coronary heart disease, stroke, colon and breast cancers, type 2 diabetes and hypertension (World Health Organization, 2010). In addition to physical disorders, regular activity can reduce risk of depression, dementia and Alzheimer's, as well as improve psychological wellbeing (Department of Health, 2011). There is also strong evidence that physical activity has a favourable impact on energy balance and weight maintenance (US Department of Health and Human Services, 2008).

The benefits of physical activity (or risks of inactivity) are evident throughout the life course. Figure 2.2 models the progression of risk throughout life of inactive (upper line) and active individuals. Physical inactivity has negative effects at all life stages beginning in childhood, although these may not be fully expressed as disease or early mortality until mid-adulthood (Department of Health, 2011). The promotion of physical activity is therefore of great importance for individuals of all ages. Furthermore, there is a dose-response relationship between physical activity and health, meaning that greater physical activity participation yields greater health benefits. The curvilinear relationship also means that on a population level, the greatest health gains occur when people move from inactivity to at least some low or moderate physical activity (Department of Health, 2011).

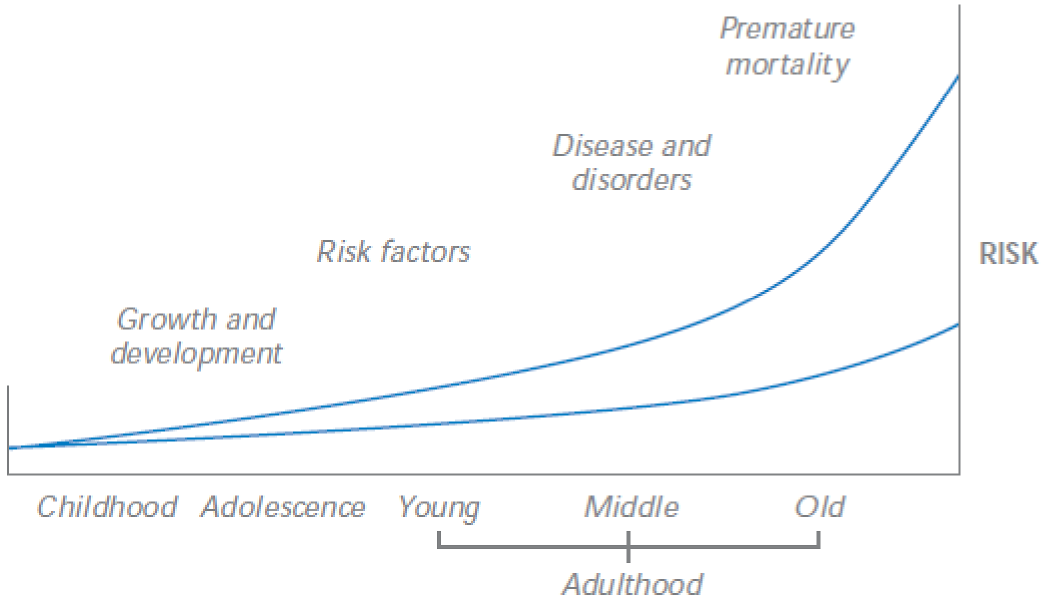



Figure 2.2 *Theoretical model of life course disease development for inactive (upper line) and active individuals.*

*Source*: Department of Health (2004).

### 2.2.3 Links between physical activity and children's health.

The United Nations Convention on the Rights of the Child defines a child as any human being under the age of 18 years (United Nations General Assembly, 1989). Physical activity during childhood years impacts child health and adult health. Comprehensive reviews suggest that compared to those who are inactive, children who are physically active have greater cardio-respiratory fitness, stronger muscles and bones, less body fat, reduced anxiety and fewer depressive symptoms (Janssen & Leblanc, 2010; US Department of Health and Human Services, 2008). Chronic health problems such as heart disease, type 2 diabetes and hypertension are not typically diseases of childhood. However, as demonstrated by Figure 2.2, physical activity during childhood protects against risk factors for these diseases which may present in later life. Indeed, the evidence base indicates that children who are physically active have favourable cardiovascular and metabolic disease risk profiles (Janssen & Leblanc, 2010; US Department of Health and Human Services, 2008). Physical activity during childhood therefore has important immediate and long term public health implications.

### 2.2.4 Physical activity guidelines.

The body of evidence linking physical activity to health is convincing. Since this behaviour is so clearly related to health, it is the responsibility of governments to educate citizens of this relationship and promote physical activity. In 2011, the United Kingdom's four Chief Medical Officers published collaborative physical activity guidelines for the first time. These guidelines drew from similar reports from the USA, Canada and the World Health Organization (Janssen & Leblanc, 2010; US Department of Health and Human Services, 2008; World Health Organization, 2010). The guidelines emphasise the consensus view that physical activity confers health benefits throughout the life course, providing age appropriate guidelines for four life stages. This thesis uses the guidelines for children and young people (aged 5-18 years) to inform many aspects of the research that follows. The Department of Health (2011) recommends that:

- All children and young people should engage in moderate to vigorous intensity physical activity for at least 60 minutes and up to several hours every day.
- Vigorous intensity activities, including those that strengthen muscle and bone, should be incorporated at least three days a week.
- All children and young people should minimise the amount of time spent being sedentary (sitting) for extended periods.

It should be made clear that the work in this thesis pertains to efforts to increase the proportion of children meeting the first of these recommendations. Moderate to vigorous physical activity (MVPA) is the intensity of physical activity required to stimulate the cardiorespiratory, musculoskeletal and metabolic systems (Department of Health, 2011). The available data indicate that the majority of children will accrue health benefits by engaging in physical activity of at least moderate intensity for one hour per day (Janssen & Leblanc, 2010). In addition, since there is a dose-response relationship between physical activity and health, children who exceed these recommendations (through either greater duration or intensity) will receive additional benefits (Department of Health, 2011). Perhaps more importantly, children who are very inactive will be rewarded health benefits if they start to engage in at least some activity.

### 2.2.5 Physical activity participation.

The previous sections indicate that regular MVPA is important for health and that the UK Government has made public health recommendations to this effect. Recording what proportion of the population meets these recommendations is complex because MVPA is not easy to classify or measure. Furthermore, the problems of recording and identifying MVPA are exacerbated in children due to the changes which occur during natural growth and development (Corder, Ekelund, Steele, Wareham, & Brage, 2008). One method of identification is to use METs to classify all physical activity behaviours with a MET score of 3.0 and above as MVPA. However, applying adult MET scores to children's behaviour may result in errors because the cost of movement per unit mass declines with age (Ridley, Ainsworth, & Olds, 2008). Perhaps a more practical explanation of MVPA for children is movement which causes faster breathing, faster heart rate and increased body temperature (Department of Health, 2011). Consequently, a wide range of behaviours occurring in many different contexts meet the requirements of MVPA, and thus, at least in theory, there are ample opportunities for most children to meet current guidelines.

Despite the apparent benefits, a large proportion of the worldwide population does not engage in sufficient physical activity. Worldwide, 31.1% of adults are physically inactive. This figure rises with age, is higher for women and more pronounced in high-income countries (Hallal et al., 2012). Focusing on children, the Health Behaviour in School-Aged Children (HBSC) study is an extensive data set including youth aged 11-15 from 39 European and North American countries. The 2009/2010 wave of the investigation indicated that 27% of 11 year olds, 19% of 13 year olds and 15% of 15 year olds report one hour of MVPA participation every day (Currie et al., 2012). Self-report data from the 2010 HBSC Survey in Scotland revealed that just 11% of girls and 19% of boys reported meeting physical activity guidelines (Currie et al., 2011). Another large (n=5595) UK study using accelerometry reported that only 5.1% of boys and 0.4% of girls recorded sufficient levels of physical activity (Riddoch et al., 2007).

In comparison, data from the European Youth Heart Study which also used accelerometry but with a lower threshold for MVPA, indicated that ~97% of nine year olds and at least 62% of 15 year olds recorded one hour of MVPA per day (Riddoch et al., 2004). Thus the proportion of children meeting the current physical activity recommendations can vary by measurement tool and in particular, by MVPA cut-point when using accelerometers (Ekelund, Tomkinson, & Armstrong, 2011). Disparity between accelerometer and self-report estimates are likely due: 1) underestimation of physical activity resulting from the inability of accelerometry to record physical activity during load carrying, using stairs or during swimming and cycling activities (Sirard & Pate, 2001; Welk, Corbin, & Dale, 2000); and 2) overestimation of physical activity by self-report methods resulting from recall bias or over-reporting owing to opinions and perceptions held by the participant (Corder et al., 2008). These methodological issues (which will be discussed further in section 2.3) and the lack of data supporting a decline in children's physical activity in recent years should not detract from the evidence indicating few children are sufficiently active and that interventions are required (Ekelund et al., 2011).

In 2009, physical inactivity was reported to be the fourth leading risk factor for global mortality, accounting for 6% of deaths worldwide (World Health Organization, 2009). In 2008, it is estimated that 5.3 million people died because of inactivity, equivalent to the number whose deaths were caused by tobacco use (Lee et al., 2012). These figures are disputed because of the generalisation of data from mostly North American and European adult cohorts to individuals of all ages living across all geographic regions (Lim et al., 2012). However, even more cautious estimates place physical inactivity in the top ten risk factors ranked by attributable burden of disease, accounting for 2.7 to 3.2 million deaths in 2010 (Lim et al., 2012). The combination of high risk and high prevalence of physical inactivity results in a considerable, avoidable, health and economic burden. In 2006/2007 physical inactivity cost the United Kingdom National Health Service £0.9 billion (Scarborough et al., 2011). In the recent *Lancet* series on physical activity, Kohl, Craig, Lambert et al. (2012) suggest that:

"In view of the prevalence, global reach, and health effect of physical inactivity, the issue should be appropriately described as pandemic, with far-reaching health, economic, environmental, and social consequences."

Physical activity promotion should be a major public health priority. It is therefore necessary to better understand physical activity behaviours, and use this knowledge to develop interventions that increase participation. Promoting physical activity during childhood is important because it enhances health during both childhood and in later life.

## 2.3 Methods of Measurement of Children's Physical Activity

As described in section 2.2, development of accurate methods is the second of five stages of research within the behavioural epidemiological framework. High quality measures are essential for research occurring for all other stages, and findings are refined as more advanced methods are validated (Sallis et al., 2000a). Physical activity must be measured in order to understand the strength and nature of associations with health outcomes, to identify the factors that influence physical activity participation, and evaluate the efficacy of interventions that aim to increase physical activity (Dollman et al., 2009; Sallis & Owen, 1999). Inaccurate measures may attenuate or overestimate these relationships, or when error is particularly severe, limit the ability of a study to detect actual relationships between variables, i.e. increase the chance of type II error (Ainsworth et al., 2012). It is therefore vital to recognise the strengths and weaknesses of the various physical activity measurement tools, and the circumstances in which each may be administered.

Physical activity is difficult to measure because it is a complex group of behaviours rather than a single act (Sallis & Owen, 1999). These difficulties are often exacerbated in child populations because of the cognitive, physiological and biomechanical changes that occur during growth and development (Corder et al., 2008). Children also have a shorter attention span, poorer economy of movement, fatigue more quickly, require frequent rest periods and are less interested in continuous activity (Welk et al., 2000). Children's physical activity is often spontaneous, unplanned and intermittent

(Bailey et al., 1995; Baquet, Stratton, Van Praagh, & Berthoin, 2007), making it difficult to recall, quantify and categorise (Sirard & Pate, 2001). Measurement of physical activity in children has unique challenges which may not be resolved with solutions generalised from adult research.

The dimensions of physical activity include intensity, duration and frequency, which together quantify the total volume or amount of activity. Summarising the volume of physical activity according to the dimensions of type or context provides a description of where, when and in what way physical activity occurs. A wide range of tools have been used to measure physical activity in youth, each recording one or more of the dimensions of physical activity. An ideal measurement tool would accurately record all of the dimensions of physical activity simultaneously; however, at present no such tool exists (Trost, 2007). This section describes the strengths and limitations of techniques for measuring physical activity in youth populations. Criterion standard, objective and subjective methods of assessment are discussed separately. Characteristics of methods are summarised in Table 2.1.

### 2.3.1 Criterion standards.

Criterion standard methods include indirect calorimetry, doubly-labelled water and direct observation. Indirect calorimetry and double labelled water are recognised as the ‘gold standard’ measures for physical activity in lab and field work respectively (Welk et al., 2000). Movement results in energy expenditure and both of these methods use this relationship to estimate physical activity. However, total human energy expenditure also includes resting metabolism and the thermic effect of eating (Kohl, Fulton, & Caspersen, 2000), which must be taken into consideration when using energy expenditure as a proxy for physical activity. Indirect calorimetry uses oxygen consumption and carbon dioxide production to estimate energy expenditure. This method is considered an accurate and valid measure of short term physical activity, however the necessary gas analysis equipment is non-portable making measurement of free living or habitual activity over a number of days infeasible (Sirard & Pate, 2001).

The doubly labelled water method involves ingestion of a radio-labelled water isotope ($^2H_2{}^{18}O$). Subsequently the oxygen atoms isotopically equilibrate with oxygen atoms in body water and expired carbon dioxide. The difference between elimination rates of $^2H$ as water, and $^{18}O$ as both water and carbon dioxide can then be used to estimate carbon dioxide production and thus energy expenditure (Schoeller et al., 1986). The advantages of this method include low participant reactivity to the assessment, ease of use in free living participants and accuracy to within 5-10% of calorimeter values in children (Goran, 1994). Unfortunately the cost and difficulty of obtaining $^2H_2{}^{18}O$ isotopes make this method unsuitable for large studies. More importantly, doubly labelled water is a highly accurate measure of the total energy expenditure over one or two weeks, but it is not possible to investigate the pattern of physical activity, i.e. the duration or frequency of bouts or how intensity changes with time (Trost, 2007).

Table 2.1 *Attributes of methods to measure children's physical activity.*

| Method | Output | Suitable for use in free living youth | Objective | Captures contextual data | High resolution pattern of activity | Cost | Ease of admin |
|---|---|---|---|---|---|---|---|
| Indirect calorimetry | Oxygen consumption | ✗ | ✓ | ✗ | ✗ | High | Complex |
| Doubly labelled water | Carbon dioxide production | ✓ | ✓ | ✗ | ✗ | High | Simple |
| Direct observation | Activity rating | ✗ | ✓ | ✓ | ✓ | High | Complex |
| Questionnaire/diary | Duration or frequency of bouts | ✓ | ✗ | ✓ | ✗ | Low | Simple |
| Pedometry | Steps | ✓ | ✓ | ✗ | ✗ | Low | Moderate |
| Heart rate monitoring | Beats per minute | ✓ | ✓ | ✗ | ✓ | Moderate | Complex |
| Accelerometry | Movement counts | ✓ | ✓ | ✗ | ✓ | Moderate | Moderate |

*Note:* Adapted from Welk et al. (2000) and Trost (2007). 'High resolution' defined here as a record of the intensity of physical activity at an epoch ≤ 1 minute. 'Suitable for use in free living youth' refers to use of given tool to measure total habitual daily physical activity rather than physical activity occurring in specific domains. For example the System for Observing Play Leisure Activity in Youth (SOPLAY) tool (McKenzie, Marshall, Sallis, & Conway, 2000)} is used primarily in controlled settings such as school recess or physical education, but would not be practical for capturing physical activity occurring before and after school when setting is unconfined.

Direct observation is perhaps a more practical criterion measure of physical activity. This technique involves observation in home or school settings. Using pre-set coding strategies, the child's activity level is logged on a computer or coding form at intervals between three seconds and one minute, depending upon the observational system employed. This instantaneous logging permits detailed examination of the pattern of physical activity and sudden changes in intensity, which is crucial for the study of children (Sirard & Pate, 2001). Methods such as the System for Observing Play Leisure Activity in Youth (SOPLAY) have strong evidence of concurrent validity with accelerometry, heart rate monitoring and indirect calorimetry (McKenzie, 2002). In addition to accurately quantifying physical activity, the flexibility of direct observation means this method can provide contextually rich data, including the location, environmental conditions and presence of others (McKenzie, 2002; Trost, 2007). Limitations of this technique include reactivity to observers and the inability to observe children over longer periods of time. Furthermore, this method is labour intensive and expensive due to training and data coding requirements (Trost, 2007), and thus not suited to larger studies.

Criterion standard measures provide accurate but often impractical measures of physical activity. Whilst measures of total physical activity energy expenditure are important, the dimensions of duration, intensity and frequency are required to answer some research questions. Using these methods it is not possible to measure the pattern of physical activity directly for long periods of time. Instead this must be inferred from other data such as answers to questionnaires, biomechanical movement or physiological markers (Corder et al., 2008).

### 2.3.2 Subjective methods.

Subjective methods include recall questionnaires and physical activity dairies. These can be completed by the child themselves (self-report) or by an appropriate adult such as a parent or teacher (proxy-report), and can also be administered by an interviewer. These methods are considered subjective because they are reliant on responses from a participant (Sirard & Pate, 2001).

Physical activity questionnaires ask the participant to recall their physical activity during a specified time period, which can range from as little as one day to as much as one year (Sirard & Pate, 2001). Recall questionnaires vary greatly in the detail with which they assess the dimensions of physical activity (Trost, 2007). For example, some recall questionnaires are used to classify individuals into broad levels of physical activity participation (e.g. inactive, active, and highly active). Other more detailed questionnaires aim to capture the type, frequency and duration of activities. This information is then often used to estimate minutes of MVPA or total energy expenditure using METs (Ainsworth et al., 2000; Ridley et al., 2008). Providing a slightly different option, activity dairies divide the 24 hour day into predetermined segments, often 15 minutes long (Bratteby, Sandhagen, Fan, & Samuelson, 1997). Diaries require the individual to record specific activities during each segment, sometimes from a list ranked by intensity.

Subjective measures are a convenient and low cost means to collect physical activity data quickly from a large number of individuals. Other advantages include low participant burden and versatility; these methods can be tailored to suit the requirements of specific research questions and can be used to record the specific type and context of physical activity (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2009; Trost, 2007).

Unfortunately, subjective methods are particularly prone to measurement error. This can be due to deliberate over-reporting owing to social desirability bias, or the result of recall bias. Physical activity recall is a complex task, and children may lack the cognitive ability to recollect the intensity, frequency and particularly the duration of activities (Baranowski et al., 1984). In addition, children may not correctly interpret questionnaires, or not fully understand the meaning of abstract terms such as "moderate to vigorous physical activity" (Trost et al., 2000a). Of course, it is also possible that measurement error results from poorly designed non-validated questionnaires using language unsuitable for young participants. The spontaneous and sporadic nature of children's physical activity also complicates recall and quantification (Bailey et al., 1995; Baquet et al., 2007). Most subjective methods are designed to measure physical activity occurring during defined periods. This may be suitable for more salient organised events, but questionnaires are likely inappropriate for children's unplanned or unstructured play, a frequent and valuable source of physical activity (Kohl et al., 2000). Proxy reports and interviewer administered methods are subject to many of the same strengths and weaknesses described above (Sirard & Pate, 2001). In particular, proxy reports are dependent upon the respondent observing the child's physical activity, while diary methods are often limited by high burden, low response rate and participants not following instructions (Sallis & Saelens, 2000).

Questionnaires and diaries are typically validated using measures such as doubly labelled water, accelerometry or heart rate monitoring. Given their widespread use and notable limitations, the reliability and validity of subjective measures have been reviewed extensively. Helmerhorst, Brage, Warren, Besson, and Ekelund (2012) recently conducted an exhaustive review of the reliability and validity of physical activity questionnaires. Median reliability correlations were acceptable to good (0.64-0.65), while median validity correlations were poor to acceptable (0.25-0.38). Only two questionnaires demonstrated acceptable to good results for both reliability and validity in youth populations (Allor & Pivarnik, 2001; Martinez-Gomez, Calabro, Welk, Marcos, & Veiga, 2010). Previous articles report that the validity of interviewer administered methods is stronger, however these techniques may introduce an additional source of bias (Sallis & Saelens, 2000; Sirard & Pate, 2001). Diary methods appear to be valid at group level, with only a 1.2% mean difference from total energy expenditure measured by doubly labelled water (Bratteby et al., 1997).

In summary, subjective methods hold several advantages, most notably their ease of administration and ability to record contextual information. Whilst it is possible to rank individuals using subjective methods, limited validity suggests questionnaires should not generally be used to measure MVPA or total physical activity energy expenditure (Corder et al., 2009). Subjective methods are therefore more suitable for large scale surveillance studies but are likely inadequate for investigating detailed patterns of intensity and duration of activity.

### 2.3.3 Objective methods.

Objective methods use measures of physiological or biomechanical markers to estimate physical activity. These methods are considered objective because they do not require children to recall or record their behaviours, and thus avoid many of the sources of bias associated with subjective measures.

#### *2.3.3.1 Pedometry.*

Pedometers assess physical activity by recording the number of steps taken over a set period of time. Pedometers are most often worn on the hip and count steps using springs or piezo-electric crystals. They are relatively inexpensive and record steps automatically without requiring responses from the participant (Sirard & Pate, 2001). Most pedometer models measure only the total number of steps, and cannot be used to investigate the intensity, duration or frequency of bouts of physical activity (Corder et al., 2008). There is however evidence of good concurrent validity (r = 0.80-0.97) with direct observation (Kilanowski, Consalvi, & Epstein, 1999), and maximal oxygen consumption (r = 0.62-0.92) during treadmill locomotion (Eston, Rowlands, & Ingledew, 1998). Pedometers are therefore best suited for use in large studies for which other methods may be to too expensive and when total ambulatory physical activity is the outcome of interest (Corder et al., 2008).

#### *2.3.3.2 Heart rate monitoring.*

Heart rate provides an estimate of the relative stress placed upon the cardiopulmonary system by physical activity (Armstrong, 1998). It is relatively inexpensive and straightforward to record heart rate at regular intervals (typically one minute) in free living individuals for extended durations (Trost, 2007). Unlike pedometry, heart rate monitoring can be used to investigate both the pattern and total volume of physical activity (Sirard & Pate, 2001).

Heart rate monitoring does not measure physical activity directly but is instead based upon the linear relationship between heart rate and oxygen consumption during steady-state exercise (Rowlands & Eston, 2007). However, there are many factors besides physical activity correlated with heart rate. These include age, body size, hydration, emotional stress, environmental conditions, active muscle group(s) and whether the activity is continuous or intermittent (Armstrong & Welsman, 2006; Rowlands, Eston, & Ingledew, 1997). The noise created by these factors is greatest during low intensity activity, meaning the oxygen consumption – heart rate relationship is less robust than during MVPA. Children with greater fitness also have a lower heart rate for a given activity; as such heart rate may be more representative of a child's fitness than activity level (Rowlands et al., 1997). A further limitation is that since heart rate lags behind movement and can remain elevated after activity has ceased, potentially important patterns of activity may be obscured (Rowlands et al., 1997).

To limit these effects, it is possible to use the flex heart rate method. Using this approach, all heart rates below an individually pre-defined threshold (the flex heart rate) are assumed to be equal to resting energy expenditure. Above the flex heart rate, individually calibrated heart rate – oxygen consumption regression equations are used to predict oxygen consumption. Livingstone et al. (1992) successfully used this method to predict group mean energy expenditure when compared to doubly labelled water values (mean group differences ranging from -9.2 to 3.5%). However the increased burden of individual calibration in a laboratory setting limits use of this technique for larger studies (Armstrong & Welsman, 2006).

Despite the above limitations, heart rate monitoring provides a reliable and valid objective method to estimate the pattern and total volume of physical activity (particularly MVPA) in free living children, and is cost effective for small to medium size investigations (Sirard & Pate, 2001).

#### *2.3.3.3 Accelerometry.*

Accelerometers are the most commonly used objective measure of physical activity in youth populations (Corder et al., 2008). Accelerometers measure movement directly by recording acceleration in one, two or three axes (depending on the individual unit). These devices have excellent data storage and can summarise movement at user defined epochs as short as one second, accounting for the highly intermittent pattern of children's physical activity (Bailey et al., 1995; Baquet et al., 2007). Accelerometers therefore permit highly time resolved investigation of the pattern, intensity and total accumulation of physical activity over many days. The units are small, lightweight, durable and less burdensome than heart rate monitors which require electrodes or chest straps (Trost, 2007). A wide variety of accelerometer models are available with a large number of studies assessing their reliability and validity. The majority of these studies report strong positive correlations with energy expenditure and physical activity intensity (Trost, McIver, & Pate, 2005).

Limitations include inability to record physical activity during load carrying, using stairs or during swimming and cycling activities (Sirard & Pate, 2001; Welk et al., 2000). Another important limitation is the absence of contextual data, meaning the type, location or other important environmental conditions cannot be investigated using accelerometer data alone.

In addition to these inherent limitations, there are a number of methodological uncertainties associated with the collection and interpretation of accelerometer data. One issue regards the choice of accelerometer unit. Many different units exist, of which the most widely used are those produced by ActiGraph (Pensacola, Florida, USA), previously known as the CSA, the MTI and the WAM (Sasaki, John, & Freedson, 2011). More recent ActiGraph devices include the bi-axial GT1M and its replacement in 2009, the tri-axial GT3X. Measurement in three axes should theoretically improve the precision of estimates of activity as movement rarely occurs in one plane. However, recent evidence suggests that uni-axial (vertical axis only) output is comparable between these devices and that there is no significant advantage of using three axes rather one axis for estimating physical activity energy expenditure in a youth population (Hanggi, Phillips, & Rowlands, 2013). Trost et al. (2005) have also reported that there is no evidence to support recommendation of any accelerometer unit in preference to others, meaning unit selection is a choice based upon unit cost, unit design, memory size and reliability. Accelerometers normally quantify physical activity in arbitrary units called counts which are not comparable between brands (Reilly et al., 2008). Consequently, choice of accelerometer may also be guided by a desire to be able to compare findings with those of other studies using the same model or brand (Trost et al., 2005).

Since accelerometers summarise movement using counts per unit time, these arbitrary units must be converted into a more useful estimate of physiological intensity (Corder et al., 2008; Reilly et al., 2008). Thresholds termed 'cut-points' derived from calibration studies are often used to quantify minutes of light, moderate and vigorous intensity physical activity. Of particular importance is the cut-point used to classify minutes of MVPA and thus assess children's attainment of the guideline amount of 60 minutes per day (Department of Health, 2011). Use of such cut-points is controversial because multiple calibration studies have been conducted, resulting in diverse cut-points ranging from 615 counts per minutes (Metallinos-Katsaras, Freedson, Fulton, & Sherry, 2007) to 3600 counts per minute (Puyau, Adolph, Vohra, & Butte, 2002). Using such cut-points, it is possible to show that the same group of children wearing the same accelerometer are either sufficiently, or insufficiently active (Corder et al., 2008; Reilly et al., 2008). Decisions about epoch duration, number of days of measurement and compliance add further complexity; however despite the need for further research to resolve these uncertainties, accelerometers can provide very rich data and remain an excellent tool for objective assessment of children's physical activity patterns (Rowlands & Eston, 2007).

#### 2.3.4 Summary.

Since there is no measurement tool that is ideal in all situations, the choice of measure depends upon factors including study size, budget and available staff (Rennie & Wareham, 1998). However, the primary concern when choosing an appropriate measurement tool is the research question, and the dimensions of physical activity which need to be recorded.

### 2.4 Understanding and Influencing Physical Activity Behaviours

Section 2.2 underlined the need for interventions that increase physical activity participation in children and young people. This section explains the theoretical framework used to guide investigation of the factors which make some children more active than others. It then provides justification for studying specific rather than aggregated physical activity behaviours, and concludes by proposing a classification system to categorise physical activity for this purpose.

### 2.4.1 Ecological models of health behaviour.

Developing and improving interventions relies upon an understanding of the factors influencing physical activity. Stage three of the behavioural epidemiological framework proposes that this understanding is acquired in two phases (Sallis et al., 2000a). Firstly, the demographic correlates of behaviour are identified, allowing groups of different sex, age, ethnicity or socio-economic status to be selectively targeted where necessary. Secondly, hypotheses about the factors influencing physical activity must be tested. Research in this phase identifies the potential mediating variables which could lie on the causal pathway between an intervention component and a change in physical activity behaviour (Bauman, Sallis, Dzewaltowski, & Owen, 2002). Together, these phases form part of the what the Medical Research Council describe as the ‘Development’ stage of complex intervention design (Craig et al., 2008). Because it would be very difficult to consider all of the possible determinants of physical activity at the same time, this research is guided by behavioural theories and models.

Theories and models used to understand physical activity behaviour include the Health Belief Model (Becker & Maiman, 1975), the Theory of Planned Behaviour (Ajzen, 1985) and the Trans-theoretical Model (Prochaska & Marcus, 1994). These theories focus predominantly on intrapersonal or psychological variables and their use has led to a dominance of interventions that target individuals. Interventions of this nature typically have small-to-moderate and temporary effects on small groups of people (Sallis et al., 2006). Cale & Harris (2006) suggest that most school based interventions are often limited by a focus on individual factors whilst neglecting broader environmental factors.

In recognition of the potential for larger, more sustainable effects which could be realised by integrating individual-level and environmental approaches (Jones, Bentham, Foster, Hillsdon, & Panter, 2007), there has been growing interest in environmental influences and use of ecological models to explain and modify physical activity. Ecological models emphasise the environmental and policy contexts of behaviour, while incorporating social and psychological factors (Sallis et al., 2008). A key principle is that influences interact between levels; healthy behaviours such as physical activity are thought to be maximised when environments and policies are supportive, when social norms and support are strong, and when individuals are educated and motivated (Sallis et al., 2008). Categories of influencing factors include intrapersonal, social-cultural, physical environmental and policy. Strategies using multiple components operating on different levels in 'complex' interventions are thought to have the best chance of success (Craig et al., 2008). A lack of multicomponent interventions working on different levels has been cited as a weakness of previous attempts at physical activity promotion in youth populations (van Sluijs, McMinn, & Griffin, 2007). As a result of this need to consider both individual and environmental determinants, the work presented in this thesis is guided by the principles of ecological models of health behaviour (Sallis et al., 2006; Sallis et al., 2008).

### 2.4.2 Increased specificity for ecological models.

Physical activity is not a single act but an entire class of varied behaviours (Sallis & Owen, 1999). This means that periods of activity are accumulated in different ways, and this is desirable because different types of physical activity can confer different health and social benefits (Giles-Corti & King, 2009). Unfortunately this makes the promotion of physical activity via intervention complex, because different behaviours and the populations who engage in them likely require specifically tailored interventions. To interpret the different varieties of physical activity in a way that is useful for promotion efforts, it is necessary to apply descriptors or classifications. As previously described, physical activity behaviours can be classified according to activity intensity. This is useful because it allows investigators to determine physical activity levels in the population and estimate the associated benefits and risks to public health. However, intensity alone reveals very little about the nature of physical activity and in isolation is not particularly useful when designing behavioural interventions.

Therefore, physical activity is often classified according to type or by any number of contextual attributes, for example the location, time period and with whom it occurs.

Considering the specific type and/or context of physical activity is important from a behaviour change perspective because different forms of physical activity may have different determinants (Caspersen et al., 1985). In contrast, using aggregated measures of physical activity makes it difficult to draw conclusions about specific behaviours occurring in specific contexts (Biddle, Marshall, Gorely, & Cameron, 2009), and studying determinants of physical activity on a broader level may result in null effects due to lack of specificity rather than lack of association (Davison & Lawson, 2006). The end result is that physical activity behaviour is poorly understood and interventions often ineffective.

As a consequence some investigators have argued the need to study both context-specific behaviours and behaviour specific determinants in order to maximise the capacity of models and interventions to predict and modify physical activity (Giles-Corti, Timperio, Bull, & Pikora, 2005a). For example, rather than studying walking in general, researching the factors influencing walking for transport in the neighbourhood could provide evidence about behaviour specific determinants, which could be more influential. These relationships may not be revealed if a general outcome measure of physical activity is used, and may not be transferable to other types or contexts of physical activity. Thus when seeking to understand and promote physical activity participation, it is of particular importance to consider how physical activity and its determinants vary by type and context (Bauman et al., 2012).

### 2.4.3 Describing physical activity.

The approach to researching the determinants of physical activity outlined above requires a method to categorise and identify the specific types and contexts of physical activity. Since there is no consensus on how children's physical activity should be categorised or labelled, and many terms are used interchangeably, this section presents a taxonomy.

#### *2.4.3.1 Type.*

The dimension of physical activity which describes the mode of human movement or specific physical actions taking place. Examples of types of physical activity, such as running, walking, swimming, cycling, kicking, throwing, carrying etc., are listed in the Compendium of Physical Activities (Ainsworth et al., 2011).

#### *2.4.3.2 Context.*

The dimension that depicts the social and physical environment in which physical activity occurs. The context is described by a combination of contextual attributes (see section 2.4.3.3). Can consist of a label which implies certain components (e.g. Hockey club), or be more descriptive using the contextual attributes of that behaviour (e.g. in the park with friends).

#### *2.4.3.3 Contextual attributes.*

The variables which define a particular context. There are a very great number of ways in which physical activity context can be categorised, but perhaps some of the more useful include: time period, weekend-day or week-day, season, weather, other participants, child or adult directed, level of supervision, volition, cost, and structured/unstructured. The context of physical activity is made up of one or many of these contextual components.

Previous authors have noted that definition of the location of physical activity is often interpreted as the context or setting (Giles-Corti et al., 2005a). Here, details of the physical location are considered contextual components alongside other descriptors of the environment and in combination form the overall context. For example, the physical location could be described by, amongst others: whether it is indoors or outdoors, the type of land use (greenspace, rural, urban etc.), or by data describing building, road and traffic density.

#### *2.4.3.4 Domains.*

Together the type and context provide detail about the physical activity taking place. Physical activities of similar type and context are often grouped into domains. The term domain is difficult to define and is also often used interchangeably with terms such as context, setting or location. Here the domain of physical activity is interpreted as the label assigned to groups of activities of similar type and with comparable contextual attributes. For example, domains of adult physical activity include active recreation, household activities, occupational activities and active commuting (Sallis et al., 2006). While there is no consensus on the number or definition of physical activity domains in children, these can include structured activities such as school physical education and organised sport or exercise, and unstructured activities such as active commuting, school recess and outdoor play (Brockman, Fox, & Jago, 2011a; Trost, 2007). The SLOTH (sleep, leisure, occupational, travel and home) model is another which seeks to describe physical activity using domains (Pratt, Macera, Sallis, O'Donnell, & Frank, 2004). Research pertaining to domains of children's physical activity is discussed further in section 2.5.2.

## 2.5 Patterns of Children's Physical Activity

The previous section has outlined how intervention design may benefit from considering the type and context of physical activity rather than aggregated measures, and presented a classification scheme for this purpose. These descriptors can be applied to investigate patterns of when, where and how physical activity levels vary. This type of research is vital for effectively designing and targeting interventions strategies.

### 2.5.1 Temporal patterns of physical activity.

Classification by time period and day is a simple but informative method of investigating the context of children's physical activity. This type of research can inform decisions about when might be the best time to intervene, and can help generate hypotheses about the factors that cause some children to be more active than others.

There is good evidence that week-day activity is greater than weekend-day activity regardless of age or sex (Aznar et al., 2011; Blaes, Baquet, Fabre, Van Praagh, & Berthoin, 2011; Hager, 2006; Klasson-Heggebo & Anderssen, 2003). Studies of primary school children (Duncan, Duncan, & Schofield, 2008; Falgairette, Gavarry, Bernard, & Hebbelinck, 1996; Nyberg, Nordenfelt, Ekelund, & Marcus, 2009; Riddoch et al., 2007; Rowlands & Hughes, 2006) and secondary school children (Armstrong, Balding, Gentle, & Kirby, 1990; Hohepa, Schofield, Kolt, Scragg, & Garrett, 2008; Sirard, Kubik, Fulkerson, & Arcan, 2008) have also reported physical activity to be greater on week-days than on weekend-days.

Differences in physical activity participation between week-days and weekend-days are particularly clear when inspecting the hourly pattern. Riddoch, Mattocks, Deere et al. (2007) conducted a large accelerometer study of 5595 children aged 11-12 years over seven days, plotting physical activity intensity (counts per minute) by hour. Figure 2.3 demonstrates the difference between the flat, smooth pattern of activity on weekend-days and the peaks and troughs of physical activity on week-days.

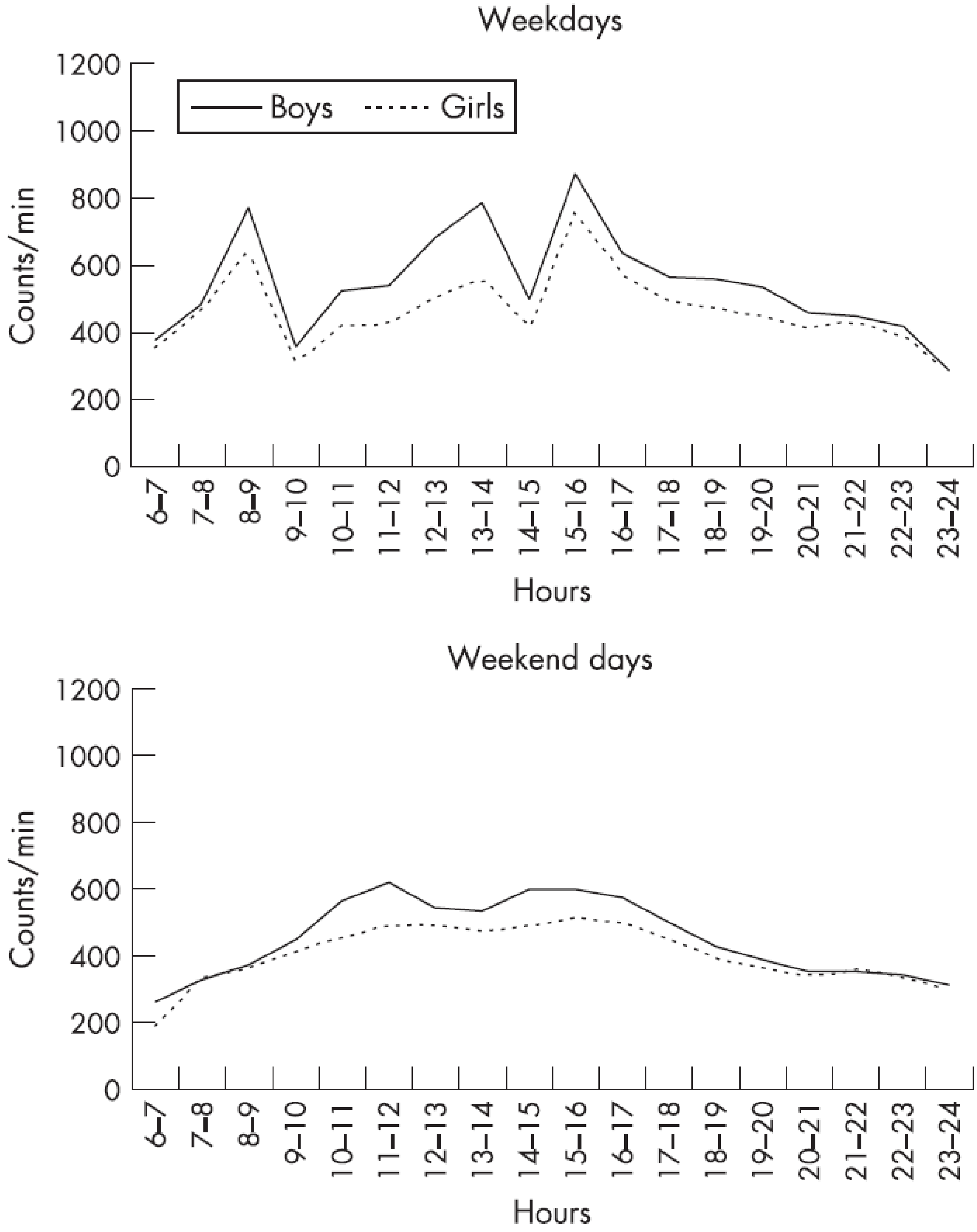



Figure 2.3 *Weekday and weekend median counts per minute from 06:00-00:00 in 9-10 year old girls and boys.*

Source: Riddoch et al. (2007).

Sources of physical activity on week-days can include two periods of recess, physical education classes and occasionally, after school sport. Some children also commute actively to and/or from school. The pattern revealed by Riddoch et al. (2007) is indicative of these periods of physical activity (physical education is obscured as it occurs at different times). Hager (2006) reported a similar pattern in 9-12 year olds, citing the period 15:00 to 18:30 as that with the highest intensity physical activity. Ridgers, Graves, Foweather and Stratton (2010) examined minutes of physical activity in a sample of 9-10 year old children based on individually calibrated accelerometer thresholds. Physical activity level was highest from 12:00 to 13:00, however peaks of activity were also present from 08:00 to 09:00 and from 15:00 to 18:00. Once more these peaks of physical activity coincide with the morning travel to school period, lunch break and the time immediately after school, interspersed with periods of inactivity in the classroom. Klasson-Heggebo et al. (2003) also discovered peaks of activity at lunch time and after school in a Norwegian sample, although owing to a different school schedule these occurred at 11:30 and 13:30. Similarly, Anzar et al. (2011) measured hourly patterns of MVPA accumulation in 9 and 15 year old Spanish youth. Despite contrasting school schedules between Spain and the UK, physical activity was also higher during lunchtime and the after school period. These findings indicate that school day structure is related to when children are physically active irrespective of the hour of day. Physical activity after school attenuates as the evening progresses towards bedtime and the weekend-day pattern is typified by a comparatively flat smooth plot of low level physical activity throughout the day (Hager, 2006; Riddoch et al., 2007; Ridgers et al., 2010). Greater physical activity on week-days compared to weekend-days would therefore appear to be supported by the structure of the school day.

Given the variability of physical activity throughout the school-day, and differences between week-days and weekend-days, it is also pertinent to compare children's school-time and leisure-time physical activity. School-time is defined here as the hours of the normal school day, including recess and lunch, but excluding after school sport and activities. It is acknowledged that leisure-time can consist of activities such as chores or homework, however for the purpose of this thesis leisure-time is used as a label which defines the periods before and after school, in addition to weekends (Department of Health, 2011). Children spend 40 % of their waking time at school

(Fox, 2004), and schools have equipment, facilities and individuals trained to teach the benefits of physical activity (Stone, McKenzie, Welk, & Booth, 1998). This environment offers several opportunities for activity which should be widely accessible. Hardman, Horne and Rowlands (2009) examined physical activity during school- and leisure-time using pedometer steps in seven to eleven year old children. For both boys and girls, leisure-time steps were higher than school-time steps. Studies from Portugal, Cyprus and New-Zealand also indicate that a substantial proportion of physical activity occurs outside of school hours (Cox, Schofield, Greasley, & Kolt, 2006; Loucaides & Jago, 2008; Mota et al., 2003). Furthermore, Gidlow et al. (2008) demonstrated that school-time physical activity accounts for 29.4% of weekly MVPA measured by accelerometer, and that this proportion decreases as children progress from primary to secondary school. In contrast, Guinhouya et al. (2009) used accelerometer measurements over two days and reported that school-time (08:30 to 16:30) accounted for 70% and 73% of daily MVPA accumulation in boys and girls respectively. Using the time period 08:30 to 16:30 to represent school-time may have inflated the contribution towards daily MVPA totals by including transport to and from school and after school activities. Most studies define a much shorter school day (typically 09:00 to 15:00). Gidlow et al. (2008) demonstrated that including activity immediately before and after school markedly increases the school-time contribution (49.1% compared with 29.4%).

Thus while the between-day pattern indicates that school days are important for physical activity accumulation, the within-day pattern reveals that the majority of this activity is accumulated outside of school-time. The school day does provide opportunities for physical activity through recess and physical education, however for the most part children are sedentary in classrooms. Lower physical activity levels during school-time may therefore be expected given that there is a ceiling on the physical activity which can be accumulated. In contrast, leisure-time has greater duration and offers youth greater flexibility to engage in a greater variety of physically active or inactive behaviours (Cox et al., 2006), either through their own choice or as a consequence of determinants which bypass their decision making (e.g. parental rules).

This greater scope results in a wide range of physical activity participation ranging from very high activity to almost complete inactivity. Vincent & Pangrazi (2002) reported high inter-individual variation in daily step counts and posited that due to the similar regime each child followed throughout the school day, this variation must occur during leisure-time. Two aforementioned pedometer studies indicate that step count differences between the most and least active tertiles are greater for leisure-time than school-time (Cox et al., 2006; Hardman et al., 2009). In contrast to their more active counterparts, the very least active children were shown not to increase their activity after the restraints of school were removed (Hardman et al., 2009). Moreover, in the study by Cox et al. (2006), the very least active children were found to accumulate the majority of their activity during school-time. Riddoch et al. (2007) suggested that the period from 15:00 onwards on weekdays exhibits substantial differences between the most active and least active children. In addition, differences in MVPA accumulation between overweight and non-overweight children have been reported to be greatest before school, at lunchtime and especially during the after school period (Page et al., 2005; Treuth et al., 2007). It is therefore clear that substantial variation in physical activity participation exists during leisure-time when children perhaps have greater discretion over their behaviour (Atkin et al., 2008; Page et al., 2005).

To summarise, there is good evidence that week-days are more actively spent than weekend-days, with peaks of activity before school, at lunchtime and immediately after school. However, whilst more physical activity occurs on school-days, the majority of this activity occurs outside of school-hours during leisure-time. Physical education and recess provide an important source of physical activity for some children; however the predominantly sedentary nature of school-time would seem to place a ceiling on the volume of physical activity that can be accrued. Leisure-time is greater in duration and offers greater flexibility for children engage in either active or inactive behaviours, and consequently there is greater inter-individual variation in physical activity level outside of school. Understanding the causes of this variation will improve intervention design. Leisure-time, and particularly the ‘critical hours’ immediately following school (Atkin et al., 2008), offer great scope to have a considerable effect on children's overall physical activity levels.

### 2.5.2 Domains of children's physical activity.

Studying the temporal pattern of physical activity is informative, but this does not allow investigators to fully understand the behaviours taking place. It is however possible to draw upon the research investigating temporal patterns and hypothesise about the contributions of different domains of activity. For example, one could attribute peaks of intense activity immediately following school to active commuting and therefore seek to increase participation in this domain of physical activity.

As previously outlined, the domains of children's physical activity are not defined concretely but normally include structured activity such as physical education and structured sport or exercise during leisure-time, and unstructured activity such as active commuting, school recess and leisure-time outdoor play (Brockman et al., 2011a; Trost, 2007). The current UK physical activity guidelines state that children aged 5-18 should enjoy a balance of both structured and unstructured physical activity throughout the day. The opportunity for unstructured and structured physical activity before during and after school is also highlighted as one of the 'seven investments that work' for promoting physical activity (Global Advocacy for Physical Activity [GAPA] the Advocacy Council of the International Society for Physical Activity and Health [ISPAH], 2011). Thus alongside study of the temporal pattern, an appreciation of the relative intensity and contributions of different domains towards overall physical activity is crucial. The following sections provide an overview of the domains of children's physical activity.

#### *2.5.2.1 Physical education.*

The vast majority of children are exposed to physical education, with facilities and personnel providing a purpose made environment for physical activity participation (Fairclough, 2003b). For some children this may be their only source of MVPA. As such, physical education has been highlighted as an important contributor towards helping young people meet physical activity guidelines.

Studies from the USA using direct observation, in particular the System for Observing Fitness Instructing Time or SOFIT (Levin, McKenzie, Hussey, Kelder, & Lytle, 2001; McKenzie et al., 2006; McKenzie et al., 2000; McKenzie, Prochaska, Sallis, & LaMaster, 2004; Nader, 2003; Scruggs et al., 2003), and heart rate monitoring studies from the UK (Fairclough, 2003a; Fairclough & Stratton, 2005b; Fairclough, 2003b), have investigated the intensity of physical activity during physical education lessons. All of these studies indicate that less than half of a child's time in physical education is spent engaging in MVPA. More concerning is the fact that for most children, their exposure to physical education on any given occasion was less than one hour, meaning that approximately 20 minutes of MVPA are accrued per lesson. For example, in the study by Fairclough and Stratton (2005b), heart rate monitoring of 62 boys and 60 girls revealed that during a lesson of mean length 50.6 (20.8) minutes, 34.3% of the time was spent in MVPA resulting in 17.5 (12.9) minutes of MVPA.

The US Department of Health and Human Services has aimed for at least 50% of physical education time to be spent engaging in MVPA (US Department of Health and Human Services, 2000). It may be difficult to reach or exceed this target, because physical activity engagement is not the only aim of physical education. Other aims include development of motor skills, creativity, social and moral development; these may be incompatible with physical activity targets (Fairclough & Stratton, 2005a). Thus there may be a limit on the proportion of time that can be dedicated to MVPA accrual during physical education lessons. One approach could be to increase the frequency or duration of physical education in the curriculum. Unfortunately the amount of time dedicated to physical education is small and is curtailed as children move from primary to secondary school due to the demands of other academic areas (Fairclough & Stratton, 2005a).

#### *2.5.2.2 Structured lesiure-time physical activity.*

Structured leisure-time physical activity refers to clubs, sports matches/training, and after school programs taking place outside of the school curriculum. These have an element of formality and are commonly organised by adults. Like physical education, structured clubs and training offer a tailor made opportunity for physical activity participation, and could therefore provide a valuable source of MVPA during leisure-time.

Studies using accelerometry have reported MVPA during sports practices including soccer, baseball, basketball and flag football (Leek et al., 2011; Wickel & Eisenmann, 2007). Between 26 and 45.1 minutes of MVPA were recorded during these sessions which varied considerably in duration (60-217 minutes). Investigators using direct observation found that 20.3 (SD = 0.8) minutes of MVPA were recorded per day by children attending after school programs (Trost, Rosenkranz, & Dzewaltowski, 2008). Bringolf-Isler et al. (2009) reported that a mean of 10.7 minutes per day were spent at sports training, and that sports training was the most intense of a wide variety of behaviours recorded using a time activity diary combined with accelerometry. The comparatively limited contribution may be explained by participants being part of a larger cross-sectional study with a more heterogeneous sample, compared to the studies by Leek et al. (2011) and Wickel and Eisenmann (2007) who recruited children only from sports clubs.

There are limited data regarding the contribution of structured leisure-time physical activity towards daily MVPA and those that are available are inconsistent, ranging from 23% to 60% (Katzmarzyk & Malina, 1998; Wickel & Eisenmann, 2007). It is likely that the volume of MVPA recorded is highly variable dependent upon the sample, measurement method and the sport concerned. What is clear though is that participation in structured leisure-time physical activity does not guarantee that children meet physical activity guidelines on those days where practice occurs.

It may be possible for the volume of MVPA recorded during organised sport to be increased. Wickel and Eisenmann (2007) reported that 27% of practice time was spent in MVPA compared to 46.1% in the study by Leek et al. (2011). These values are comparable to those found for physical education. This may indicate that organised sport suffers from some of the same barriers to MVPA accumulation, for example, diverse aims including coaching of skills and tactical instruction. This hypothesis would seem to be supported by evidence from a direct observation study which reported that 43% of sport practice time was inactive (Katzmarzyk, Walker, & Malina, 2001). This comparison also indicates that different sports may give rise to greater volumes of MVPA than others, as these studies included different sports. In particular, soccer has been shown to result in significantly more MVPA than other sports (Katzmarzyk et al., 2001; Leek et al., 2011). After school programs offer another opportunity for physical activity, however the inclusion of academic and snack times may limit the MVPA recorded (Trost et al., 2008).

Thus while structured physical activity has the potential to contribute greatly towards total daily MVPA, it should not be assumed that every minute of structured physical activity is spent engaging in MVPA, or that participation guarantees that a child will meet the physical activity guideline of one hour MVPA on those days. The duration and type of club or training can limit the total volume of MVPA accumulated. Importantly, organised physical activity can only benefit those who are able to participate. Data from the USA suggest 62% of children engage in no organised sport at all (Centers for Disease Control and Prevention, 2003), suggesting there may be barriers which preclude some subgroups of the population from this domain of activity. For example, Leek et al. (2011) reported that a soccer league cost $500 per child per season. There may also be potential difficulties with transport and facilities likely vary by neighbourhood and geographic location.

#### *2.5.2.3 Recess.*

During school time, recess and physical education offer the best opportunities for children to record MVPA. However, whilst time dedicated to physical education is being reduced (Marshall & Hardman, 2000), recess occurs daily. The duration of recess varies but for example in the UK, primary school children normally have three periods of recess per day, five days per week for 39 weeks of the year (Ridgers & Stratton, 2005). Crucially there are no distracting televisions or computer games, and temporal patterns demonstrate peaks of activity at times when recess typically occurs. Recess is therefore an important opportunity for children to be physically active. School recess periods provide a less structured environment where children have some freedom to choose their behaviour and thus shares many characteristics with children's leisure-time outdoor play. The two are examined as distinct domains here because of notable differences in location, facilities/equipment, supervision, rules and freedom of movement.

Ridgers, Stratton and Fairclough (2005) investigated the intensity of physical activity during recess using accelerometry. Boys and girls recorded 28.0 and 21.5 minutes of MVPA respectively over three recess periods totalling 85.0 (SD = 16.5) minutes duration. These boys and girls were therefore active for 32.9% and 25.3% of recess time, and this is comparable to other studies (Mota et al., 2005; Stratton & Mullan, 2005). Whilst it is encouraging that some children accumulate almost half of their daily recommended MVPA during recess, this contribution could be increased. Increasing the time spent in MVPA to 40% or even 50% of recess time has been the target of low cost interventions such as coloured markings. Stratton and Mullan (2005) found that an intervention of this type increased physical activity significantly, at least in the short term. However as reported in other work (Mota et al., 2005), it should also be noted that there were large inter-individual differences in physical activity both pre and post intervention (Stratton & Mullan, 2005), indicating that individual choice may always result in some children choosing inactivity. For example, overweight boys have been found to be significantly less active during recess than their ‘normal’ weight counterparts (Stratton, Ridgers, Fairclough, & Richardson, 2007). Recess therefore represents an opportunity to contribute considerably towards daily recommended MVPA, however increasing the proportion of recess time spent in MVPA to 50% and targeting the least active children who are less receptive to physical activity remains a challenge.

#### *2.5.2.4 Active commuting.*

Active commuting may refer to walking, cycling, or other methods of non-motorised transport to and from school, plus other lcoations. Studies using accelerometry in England and The Philippines (Cooper, Andersen, Wedderkopp, Page, & Froberg, 2005; Tudor-Locke, Ainsworth, Adair, & Popkin, 2003) have shown that children who commute actively are also more active overall. Similarly, parental proxy-report data from Russia indicate that omission of active commuting meant up to 20% fewer children met physical activity guidelines (Tudor-Locke, Neff, Ainsworth, Addy, & Popkin, 2002). Cycling to school is also associated with cardiovascular fitness (Cooper et al., 2006). Measuring the volume MVPA contributed specifically by active commuting is difficult because of potential confusion with other activity occurring at the same time. However, one recent study used a combination of accelerometry and Global Positioning Systems (GPS) to quantify MVPA occurring on the walk to and from school. Children aged 11-12 years who actively commuted recorded a mean of 22.2 minutes MVPA and this represented 33.7% of their daily total, further highlighting the importance of this behaviour (Southward, Page, Wheeler, & Cooper, 2012).

Unfortunately many children do not receive these benefits because uptake of active commuting is low, at least in the UK. Compared to 40% of those born from 1932 to 1941, only 9% of 10-11 year olds born from 1990 to 1991 commute actively (Pooley et al., 2005). In 2011-2012, 42% of trips to and from school by UK children aged 5-16 years were made on foot, while just 2% were made by bike (Department for Transport, 2013). The reasons for this low participation are unclear; however parental restrictions on independent mobility and increased car use may be significant barriers.

Given the low uptake, minimal cost and high contribution of MVPA, encouraging a switch from motorised to active commuting offers great scope to help children meet current physical activity guidelines. In addition, this behaviour may act as a catalyst for physical activity in other domains, especially outdoor play (Cooper et al., 2005). The promotion of active commuting is consequently a research area that has received much attention in the last ten years.

#### *2.5.2.5 Outdoor play.*

The research relating to patterns of physical activity presented thus far suggests that there is much variation in children's behaviour during leisure-time, with some children very active and others very inactive. This may therefore be a fruitful time to promote activity due to the duration of leisure-time and the greater scope for change in these periods.

The outdoors is one context with consistent associations with physical activity. Children's time outdoors during leisure-time is up to five times more likely to be spent as MVPA than time spent indoors (Cleland et al., 2008; Cooper et al., 2010; Wheeler, Cooper, Page, & Jago, 2010). Of particular interest is outdoor play, otherwise described as unstructured outdoor physical activity during leisure-time, active free play, independent or unsupervised physical activity or simply play. Outdoor play can take many forms but key components are that it is often freely chosen, spontaneous, short lived and child directed (Bailey et al., 1995; Brockman et al., 2011a). Freedom from adult rules and structure is also an important feature of outdoor play (Brockman, Jago, & Fox, 2011b).

The limited available data suggest that this domain of physical activity can contribute greatly towards daily MVPA. (Brockman, Jago, & Fox, 2010; Wickel & Eisenmann, 2007). Furthermore, participation in outdoor play is free, does not require expensive equipment and, importantly, Mackett and Paskins (2008) have demonstrated that this form of activity consumes more calories than an equivalent structured event (e.g. 2.8 $kcal.min^{-1}$ for unstructured ball games vs. 2.4 $kcal.min^{-1}$ for structured ball games). Outdoor play also has the potential to provide unique emotional, social and cognitive benefits (Burdette & Whitaker, 2005b), and is recognised by the United Nations as a fundamental right of the child (United Nations General Assembly, 1989).

When attempting to promote physical activity it is important to target behaviours that will result in the greatest increase on overall physical activity. The targeting of behaviours which are of relatively low intensity, inaccessible to much of the population or which have a ceiling on potential increases is unlikely to have a substantial effect on physical activity participation. Encouraging outdoor play represents an opportunity to maximise children's physical activity during leisure-time. However, in comparison to school related physical activity, organised sport and active commuting, outdoor play has received relatively little attention and as such this behaviour is not well understood. The preceding sections have illustrated that interventions to promote physical activity should take into consideration the type and context of behaviour, as determinants and mechanisms of behaviour change are likely to vary. The available evidence indicates that leisure-time is an important target for interventions, and that in particular encouraging outdoor play may be a pathway to increase children's daily MVPA levels.

## 2.6 What Did This Chapter Contribute?

- Promotion of children's physical activity is a major public health priority.
- There are many methods of physical activity measurement, none of which are ideal for all research needs.
- Successful interventions require an understanding of the determinants of physical activity and mechanisms of behaviour change.
- This understanding is guided by behavioural theories. Ecological models emphasise environmental influences alongside intrapersonal factors.
- Physical activity is not a single act but a group of varied behaviours. The determinants of individual physical activities may vary and it is therefore important to consider the specific type and context of activity.
- Studying the type and context of physical activity can inform decision making about how, when and where to intervene. This is a complex task due to the variety of ways in which physical activity occurs and how these behaviours are defined and measured.
- Study of temporal patterns and the domains of physical activity point to leisure-time, and particularly outdoor play as an important target for intervention.

# Chapter Three

# Correlates and Determinants of Children's Outdoor Play: A Review of the Literature


## 3.1 Abstract

Outdoor play is a domain of children's physical activity, the promotion of which has the potential to produce great increases on overall MVPA. Outdoor play can also provide unique emotional, social and cognitive benefits. At present, outdoor play has received relatively little attention and as such this behaviour is not well understood. Guided by an ecological approach to understanding health behaviours, this review aimed to develop better understanding of the factors influencing outdoor play.

Quantitative, qualitative and mixed methods studies of children aged 5-18 years from 1990 to August 2013 were sought using four computerised databases. Strict inclusion criteria were applied to remove any studies which used aggregated measures of physical activity not specific to outdoor play. Correlates and determinants of outdoor play were categorised as: intrapersonal, social-cultural and physical-environmental, with further sub-categorisation thereafter.

Thirty-one studies were synthesised and consistent relationships were identified: parental perceptions of safety, neighbourhood social cohesion, having other children to play with, and living in a cul-de-sac were consistently related to outdoor play. Independent mobility was an important correlate and parents were identified as key 'gatekeepers' to this behaviour. Relationships were often moderated by sex, age, season, and socio-economic status (SES).

The label outdoor play may not represent some children's unstructured outdoor leisure-time. Our understanding of how, where and with whom children spend their leisure-time, or how active these periods are, is limited.

## 3.2 Introduction

The previous chapter concluded by highlighting outdoor play as a potentially valuable opportunity to enhance children's' physical activity levels. However, while the importance of promoting outdoor play has come to prominence, this behaviour has received comparatively little research attention and is not well understood. Comprehensive reviews of the determinants of physical activity are available (Davison & Lawson, 2006; Ferreira et al., 2007; Sallis, Prochaska, & Taylor, 2000b), but the determinants of outdoor play may be unique to this type and context of behaviour. Consistent with an ecological approach to physical activity promotion (Sallis et al., 2008), this review of the literature investigates the intrapersonal, social-cultural and physical-environmental correlates and determinants of outdoor play. More specifically, the review aims to highlight consistent relationships, identify target groups for intervention, and suggest topics for further research.

## 3.3 Methods

### 3.3.1 Search strategy.

Papers examining relationships between intra-personal, social-cultural and physical-environmental factors and outdoor play were located using four computerised databases (Web of Knowledge, PsychInfo, EMBASE and MedLine). Due to the variety of terminology used to define outdoor play, relevant studies were located using keywords sourced from work exploring the meaning and nature of children's outdoor play (Brockman et al., 2011a; Burdette & Whitaker, 2005a; Veitch, Salmon, & Ball, 2008). A separate search was conducted using keywords relating to children. The two searches were then combined using the 'AND' search operator. The syntax for both searches are shown in Table 3.1. Searches were conducted on the title, keywords and abstract of articles in each database. Syntax was adapted to suit input requirements of each database. Reference lists of included papers and relevant reviews were checked for additional studies using terminology that fell outside of the search parameters. The search was limited to English language studies from 1993 to August 2013. Only original articles in peer-reviewed journals were included. Review articles, opinion pieces and methodological articles were excluded, as were governmental reports and other ‘grey’ literature. Quantitative, qualitative and mixed methods studies were eligible for inclusion.

Table 3.1 *Search terms and syntax used for literature search*

| Outdoor play search terms | Child search terms |
|---|---|
| outdoor play OR active play OR free play OR out of home play OR playing outdoors OR independent physical activity OR independently physically active OR outdoor physical activity OR outdoor physical activities OR unstructured physical activity OR unstructured physical activities OR outdoor physical activities OR outdoor activities OR time outdoors OR time outside OR time spent outdoors OR time spent outside | child* OR youth* OR adoles* OR young* OR girl* OR boy* OR teenage* OR school* |

### 3.3.2 Inclusion criteria.

Duplicates were removed from the list of articles returned by the above search strategy. The remaining studies were screened against the inclusion criteria set out in Table 3.2. Potentially relevant studies were selected on the basis of their titles. A second stage of screening reviewed abstracts. Finally, the full texts of remaining papers were examined to select those which would be included in the review. At this stage, rationale for the exclusion of studies was recorded.

### 3.3.3 Data extraction.

For each study included in the review, the following were recorded: 1) author; 2) year of publication; 3) country of origin of the sample; 4) sample size; 5) age and sex of participants; 6) outdoor play outcome variable or theme; 7) research design; 8) outcome variable measure; 9) independent variables and measures. Each study was assigned a study number for identification in summary tables. Relationships between outdoor play and independent variables were first broadly grouped using *a priori* categories guided by ecological models (Sallis et al., 2008). The categories used were: 1) intrapersonal factors; 2) social-cultural factors; 3) physical-environmental factors.

Findings were then divided into further sub-groups driven by the data extracted, but also guided by sub-categories of variables used in previous reviews of related topics (Davison & Lawson, 2006; Panter, Jones, & van Sluijs, 2008).

#### 3.3.4 Synthesis.

The relationships between outdoor play and variables under the aforementioned categories and sub-categories were synthesised in thematic order. For example, this meant that findings relating to the different aspects of the socio-cultural sub-category ‘safety’ were presented according to more specific topics such as ‘crime’ or ‘traffic’. These additional groupings were not formally grouped in order to aid the flow of the text when interrelated variables were examined. Papers using similar methods to measure independent variables were also presented in order, for example, studies using parental and child perceptions of the environment were discussed separately.

The findings relating to each of these themes were summarised. The overall trend of the available evidence was reported, along with the identity and number of studies indicating that trend. One of three summary types was presented:

- ‘Evidence suggests no relationship’. The available evidence indicates a null effect for the variable.
- ‘Evidence is mixed’. The available evidence is inconclusive, with conflicting findings and no clear trend indicating whether the variable is positively or negatively associated with outdoor play.
- A description of a clear trend in the evidence for the relationship between an independent variable and outdoor play. Consistent evidence of a positive or negative association, with no or only minor conflicting findings. May show consistency across both quantitative and qualitative studies where these are available.

Table 3.2 *Inclusion criteria used to select studies.*

| Characteristic | Inclusion criteria |
|---|---|
| Physical activity domain | Outdoor play, described as children's unstructured physical activity that takes place outdoors, outwith school hours or organised sport settings, and which is mostly child directed rather than adult-led. Studies focusing on outdoor play during school recess, after school clubs or other adult-facilitated contexts were excluded. The outdoor play was required to have an activity element. Articles using a general physical activity outcome were excluded unless this was combined with contextual data meeting the above description. |
| Research type | Original studies examining relationships between outdoor play and intra-personal, social-cultural or physical-environmental factors. |
| Population focus | School-age children and young people (aged 5-18 years) as defined by the Department of Health physical activity guidelines (Department of Health, 2011). Studies of pre-school children were excluded. |
| Participant health/disability status | Participants not selected on the basis of having a specific disease, health problem or disability. |

## 3.4 Results

The search strategy yielded 4394 unique results. Figure 3.1 describes the selection and screening process. In total, 61 full texts were retrieved following screening of titles and then abstracts. A further 6 papers were provisionally included after scanning reference lists. Following evaluation of the full texts, 42 studies were deemed eligible for inclusion in the review. The majority of excluded studies used a general physical activity outcome variable, did not focus on 'active' outdoor play, or focused on a population outwith the scope of the review, e.g. preschool children.

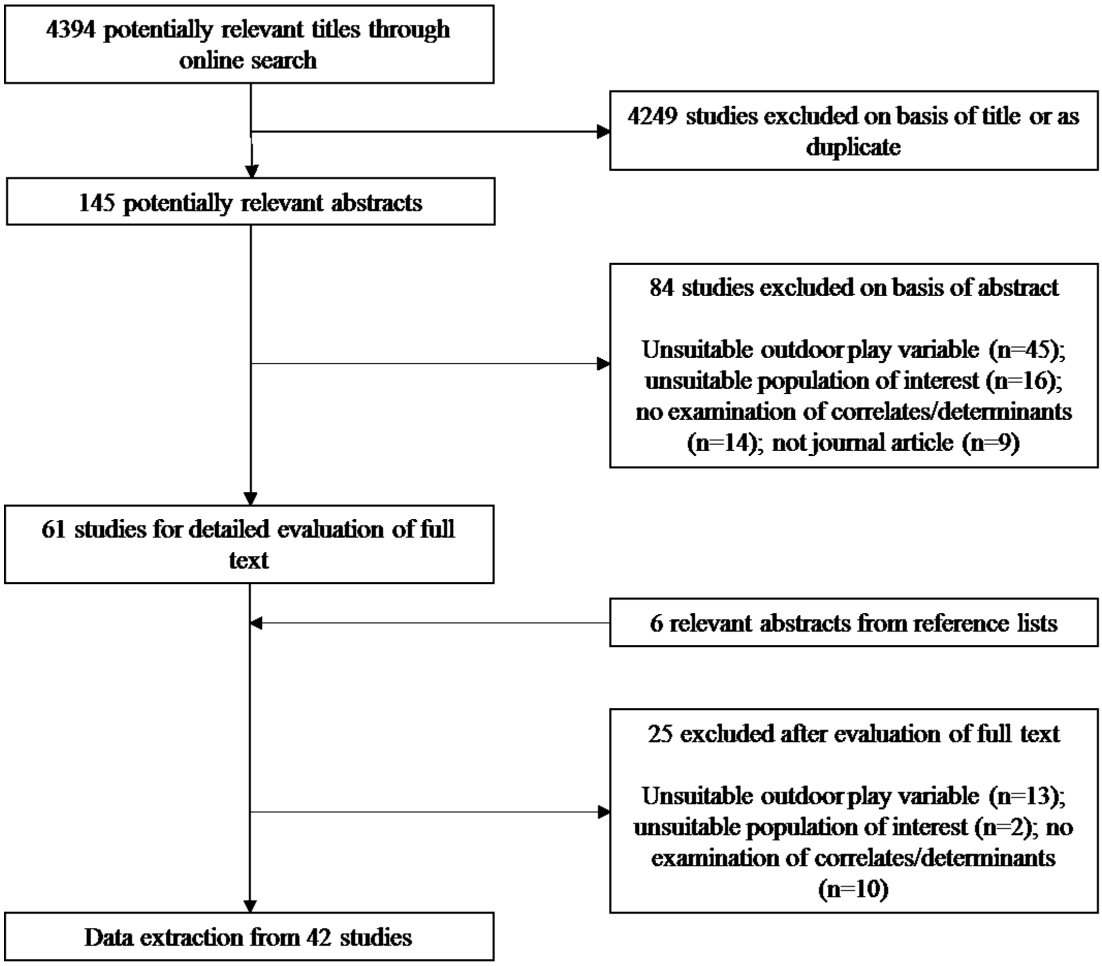



Figure 3.1 *Flow chart of selection and screening process for included studies.*

### 3.4.1 Characteristics of reviewed studies.

The review included 42 studies and characteristics of these are presented in Table 3.3. The review included 26 quantitative, 14 qualitative and two mixed methods studies. Of the 26 quantitative studies, two used a longitudinal design. Investigations were conducted in North America (11), Continental Europe (7), UK (13) and Australasia (11).

Of the 26 quantitative studies, the majority (14) used parental report, child self-report was used in nine studies, a combination of child and parental report was used once, and objective measures (GPS and accelerometry) were used twice. One of the mixed methods studies relied upon responses from parents only while the other surveyed and interviewed children only. Of the 14 qualitative studies, five studies interviewed children, five used parent interviews, three used responses from both children and parents, and one considered the views of children, parents and other adults living in the neighbourhood. Of the 42 studies included, 32 focused exclusively on children aged 12 or younger.

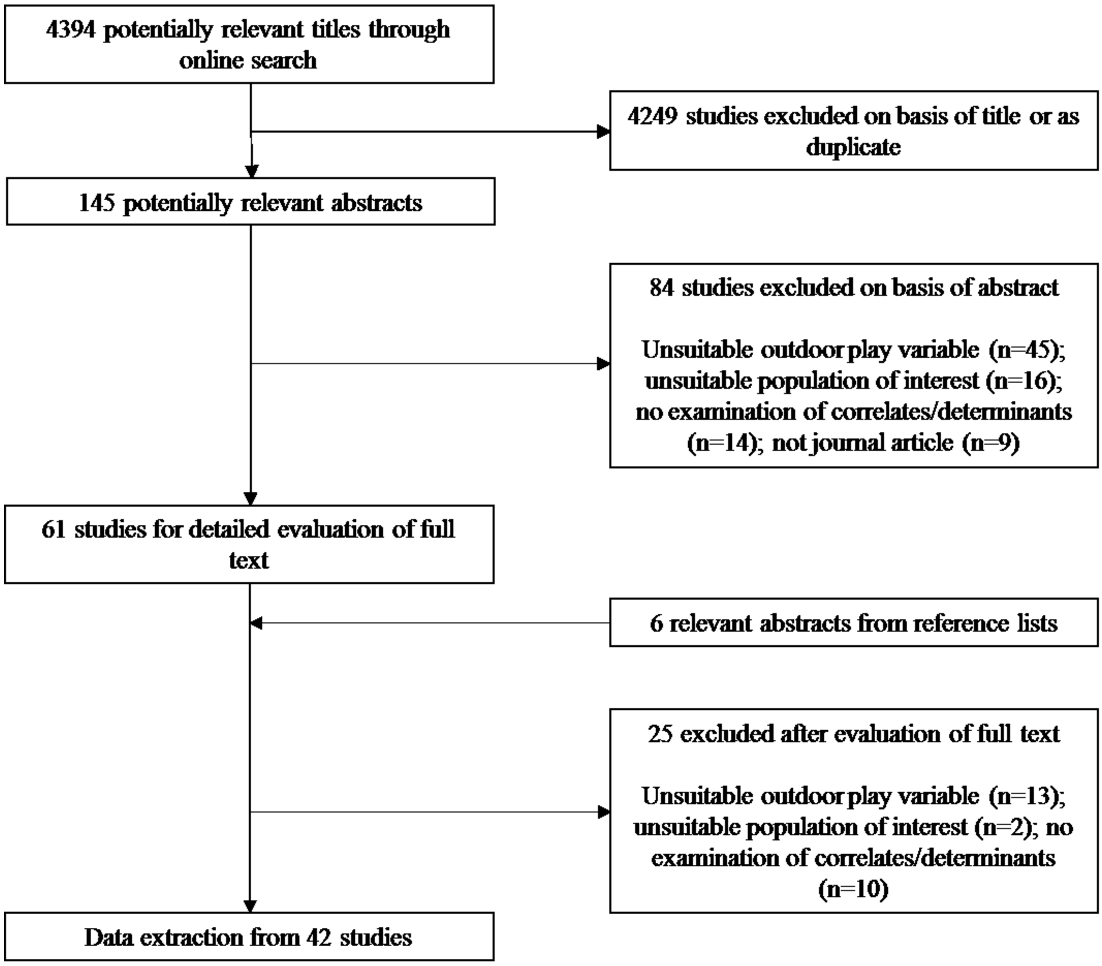



Figure 3.2 *Flow chart of selection and screening process for included studies.*

Table 3.3 *Characteristics of forty-two reviewed studies.*

| Author(s) | Study # | Participants | Child age (years) | Design | Independent variables | Outcome variable/theme |
|---|---|---|---|---|---|---|
| (Aarts, Wendel-Vos, van Oers, van de Goor, & Schuit, 2010) | 1 | 6470 parents of M&F Netherlands | 4-6<br>7-9<br>10-12 | CS | Intrapersonal<br>Social-cultural (PP)<br>Physical (PP) | Parental report: minutes of outdoor play per week (minutes per day * days per week) |
| (Aarts, de Vries, van Oers, & Schuit, 2012) | 2 | Parents of 1849 M and 1802 F Netherlands | 4-6<br>7-9<br>10-12 | CS | Intrapersonal<br>Physical (O) | Parental report: minutes of outdoor play per week (minutes per day * days per week) |
| (Anderson, Economos, & Must, 2008) | 3 | Parents of 2964 M&F USA | 4-12 | CS | Intrapersonal | Parental report: frequency of active play per week |
| (Beets, Banda, Erwin, & Beighle, 2011) | 4 | 66 M&F USA | 9-11 | Q | Social-cultural (CP)<br>Physical (CP) | Auto driven interview: free play |
| (Bringolf-Isler et al., 2010) | 5 | Parents of 1081 M&F Switzerland | 6-14 | CS | Intrapersonal<br>Social-cultural (PP)<br>Physical (PP, O) | Parental report: minutes of vigorous outdoor play per day |
| (Brockman et al., 2009) | 6 | 113 M&F UK | 10-11 | Q | Intrapersonal<br>Social-cultural (CP) | Focus group: unstructured physical activity/free play |

| Author(s) | Study # | Participants | Child age (years) | Design | Independent variables | Outcome variable/theme |
|---|---|---|---|---|---|---|
| (Brockman et al., 2011a) | 7 | 77 M&F<br>UK | 10-11 | Q | Intrapersonal<br>Social-cultural (CP)<br>Physical (CP) | Focus group: active play |
| (Brockman et al., 2011b) | 8 | 77 M&F<br>UK | 10-11 | Q | Intrapersonal<br>Social-cultural (CP)<br>Physical (CP) | Focus group: active play |
| (Cleland et al., 2008) | 9 | Parents of 548 M&F<br>Australia | 5-6<br>10-12 | L | Intrapersonal<br>Physical (O) | Parental report: weekly time spent outdoors after school |
| (Cleland et al., 2010) | 10 | Parents of 421 M&F<br>Australia | 5-6<br>10-12 | L | Intrapersonal<br>Social-cultural (PP)<br>Physical (PP) | Parental report: weekly time spent outdoors after school |
| (Collins, Al-Nakeeb, Nevill, & Lyons, 2012) | 11 | 50 M&F<br>UK | 13-14 | CS | Intrapersonal<br>Physical (O) | GPS/accelerometer: outdoor physical activity |
| (Cooper et al., 2010) | 12 | 1010 M&F<br>UK | 10-11 | CS | Intrapersonal<br>Physical (O) | GPS/accelerometer: outdoor physical activity |
| (Curtis, Hinckson, & Water, 2012) | 13 | 9 M&F and 12 parents<br>New Zealand | 8-12 | Q | Intrapersonal<br>Social-cultural (CP, PP) | Focus group: play |
| (Dias & Whitaker, 2013) | 14 | 32 mothers of Black F<br>USA | 9-13 | Q | Social-cultural (PP)<br>Physical (PP) | Interview and focus group: outdoor play |

| Author(s) | Study # | Participants | Child age (years) | Design | Independent variables | Outcome variable/theme |
|---|---|---|---|---|---|---|
| (Donatiello et al., 2013) | 15 | 1673 M&F<br>Italy | 2-8 | CS | Physical (PP) | Parental report: unstructured outdoor activity |
| (Ergler, Kearns, & Witten, 2013) | 16 | 20 M&F and parents<br>New Zealand | NR | Q | Social-cultural (CP, PP)<br>Physical (CP, PP) | Semi-structured interview: outdoor play |
| (Gomez, Johnson, Selva, & Sallis, 2004) | 17 | 177 Mexican American M&F<br>USA | 12-13 | CS | Intrapersonal<br>Social-cultural (CP, O)<br>Physical (O) | Child report: recall of outdoor physical activities over past year |
| (Goodman, Paskins, & Mackett, 2012) | 18 | 325 M&F<br>UK | 8-11 | CS | Physical (O) | Child report: out-of-home play |
| (Hammond, McFarland, Zajicek, & Waliczek, 2011) | 19 | 142 parents of M&F<br>USA | 6-13 | CS | Social-cultural (PP) | Parental report: outdoor free play |
| (Holt, Spence, Sehn, & Cutumisu, 2008) | 20 | 168 M&F<br>Canada | 6-12 | CS | Intrapersonal<br>Physical (O) | Child mental mapping of play |

| Author(s) | Study # | Participants | Child age (years) | Design | Independent variables | Outcome variable/theme |
|---|---|---|---|---|---|---|
| (Jago et al., 2009) | 21 | 24 parents of M&F UK | 10-11 | Q | Intrapersonal Social cultural (PP) | Phone interview: independent physical activity |
| (Jenkins, 2006) | 22 | 15 M&F and their parents UK | 11-15 | Q | Social-cultural (PP) | Semi-structured interview: outdoor play |
| (Kalish, Banco, Burke, & Lapidus, 2010) | 23 | 254 parents of M&F USA | 5-7 | CS | Intrapersonal Social-cultural (PP) Physical (PP) | Parental report: outdoor play |
| (Karsten, 2005) | 24 | 99 children and adults Netherlands | NA | Q | Intrapersonal Social-cultural Physical | Interview: play |
| (Kimbro, Brooks-Gunn, & McLanahan, 2011) | 25 | Parents of 1822 M&F USA | ~5 | CS | Intrapersonal Social-cultural (PP) Physical (PP) | Parental report: hours of outdoor play per weekday |
| (Nilsson et al., 2009) | 26 | 1327 M&F Norway, Estonia Portugal | 9 15 | CS | Intrapersonal | Child report: outdoor play after school |
| (O'Brien & Smith, 2002) | 27 | 6 parents of M&F UK | 8 | Q | Social-cultural (PP) Physical (PP) | Semi-structured interview: play |

| Author(s) | Study # | Participants | Child age (years) | Design | Independent variables | Outcome variable/theme |
|---|---|---|---|---|---|---|
| (Page, Cooper, Griew, & Jago, 2010) | 28 | 1307 M&F<br>UK | 10-11 | CS | Intrapersonal<br>Social-cultural (CP)<br>Physical (CP, O) | Child report: frequency of play |
| (Prezza et al., 2001) | 29 | Mothers of 251 M&F<br>Italy | 7-12 | CS | Intrapersonal<br>Social-cultural (PP)<br>Physical (PP) | Parental report: child's frequentations of peers for play activities at home and outside |
| (Soori & Bhopal, 2002) | 30 | 471 parents and 476 M&F<br>UK | 7 & 9 | CS | Intrapersonal | Parent and child report of independent outdoor activities |
| (Spink et al., 2006) | 31 | 198 M&F<br>Canada | 12-17 | CS | Intrapersonal<br>Social-cultural (CP) | Child report: unstructured physical activity |
| (Thomson & Philo, 2004) | 32 | 73 M&F<br>UK | 8-9 | CS<br>Q | Intrapersonal<br>Social-cultural (CP)<br>Physical (CP) | Play |
| (Valentine & McKendrick, 1997) | 33 | 70 homes M&F<br>UK | 8-11 | CS<br>Q | Intrapersonal<br>Social-cultural (PP) | Parental report: indoor/outdoor child, perception of public play provision |
| (Veitch, Bagley, Ball, & Salmon, 2006) | 34 | 78 parents of M&F<br>Australia | 6-12 | Q | Intrapersonal<br>Social-cultural (PP)<br>Physical (PP) | Interview: play |

| Author(s) | Study # | Participants | Child age (years) | Design | Independent variables | Outcome variable/theme |
|---|---|---|---|---|---|---|
| (Veitch, Salmon, & Ball, 2007) | 35 | 132 M&F Australia | 6-12 | Q | Intrapersonal Social-cultural (CP) Physical (CP) | Focus group: use of public open spaces for free-play |
| (Veitch et al., 2008) | 36 | 212 M&F Australia | 8-12 | CS | Intrapersonal | Child behavioural mapping: active free play in various locations |
| (Veitch, Salmon, & Ball, 2010) | 37 | 187 M&F and parents Australia | 8-9 | CS | Intrapersonal Social-cultural (PP) Physical (PP) | Parental report: frequency of active free play in yard, street/court/footpath, park |
| (Wen et al., 2009) | 38 | 1362 M&F Australia | 10-12 | CS | Intrapersonal Social-cultural (CP, PP) | Child report: time spent playing outdoors after school. |
| (Weir, Etelson, & Brand, 2006) | 39 | Parents of 307 M&F USA | 5-10 | CS | Physical (O) | Parental report: weekly time engaging in play |
| (Witten, Kearns, Carroll, Asiasiga, & Tava'e, 2013) | 40 | 68 parents of M&F New Zealand | 9-11 | Q | Social-cultural (PP) Physical (PP) | Interview: independent outdoor play |

| Author(s) | Study # | Participants | Child age (years) | Design | Independent variables | Outcome variable/theme |
|---|---|---|---|---|---|---|
| (Worobey, Fonseca, Espinosa, Healy, & Gaugler, 2013) | 41 | 38 M&F<br>USA | 8-12 | CS | Physical (O) | Child report: outdoor physical activity |
| (Ziviani et al., 2008) | 42 | Parents of 318 M&F<br>Australia | 6-7 | CS | Intrapersonal | Parental report: frequency of play in backyards, parks or playgrounds, neighbourhoods |

*Abbreviations*: Male (M), female (F), cross-sectional (CS), longitudinal (L), qualitative (Q), parental perception (PP), child perception (CP), objectively measured (O).

### 3.4.2 Intrapersonal factors.

Intrapersonal factors identified were: sex, age, ethnicity, body mass index (BMI), pubertal status, health status, SES and attitudes towards physical activity. Findings are summarised in Table 3.4

Boys engage in more outdoor play than girls (Aarts et al., 2012; Aarts et al., 2010; Anderson et al., 2008; Bringolf-Isler et al., 2010; Nilsson et al., 2009; Page et al., 2010; Soori & Bhopal, 2002) and also spend more time outdoors (Cleland et al., 2008; Cleland et al., 2010). Four out of ten studies suggested that play participation decreases with age (Anderson et al., 2008; Bringolf-Isler et al., 2010; Nilsson et al., 2009; Soori & Bhopal, 2002), the remainder reporting no association however most focused only within a narrow age range (usually primary school children). Stronger evidence comes from a longitudinal study which reported that time outdoors declined significantly ($p < 0.01$) from ages 5 to 10 and from ages 10 to 15 (Cleland et al., 2010). Children with BMI ≥ 95$^{th}$ percentile were less likely to engage in play (Anderson et al., 2008), however two studies demonstrated no significant association between BMI and play (Cleland et al., 2008; Page et al., 2010). White children engage in more outdoor play than those who are black or Hispanic (Anderson et al., 2008; Kimbro et al., 2011). Spanish speakers were less likely ($p < 0.008$) to be allowed to play outdoors than English speakers (Kalish et al., 2010). Child health (Kimbro et al., 2011) and pubertal status (Page et al., 2010) were not related to time spent playing outdoors.

Nine quantitative studies reported associations between outdoor play and household SES (rather than neighbourhood SES), with a variety of markers employed. Each additional level of parental education (low, medium, high) resulted in an approximate 5% reduction in minutes of weekly outdoor play in two studies (Aarts et al., 2012; Aarts et al., 2010), with four other studies reporting no association. One study reported that children with a mother in part time (-14%; $p < 0.001$) or full time (-13%; $p < 0.001$) employment recorded fewer hours of parent reported outdoor play per week-day (Kimbro et al., 2011). In contrast it was reported that parental employment either full or part time (compared to ‘other duties’) meant that children were more likely (odds ratio [OR]: 1.37; $p = 0.02$) to report engaging in more than 30 minutes of outdoor play per day (Wen et al., 2009). Per capita income (Gomez et al., 2004) and household income to needs ratio (Kimbro et al., 2011) had no association with outdoor play.

Seven studies reported associations between neighbourhood SES and outdoor play suggesting an inverse relationship. Aarts et al. (2010) reported that higher SES was related to 5-7% ($p < 0.05$) fewer minutes of weekly MVPA. Page et al. (2010) reported no independent association between neighbourhood index of multiple deprivation (IMD) and play in a group of 10-11 year olds. Soori & Bhopal (2002) reported that children attending schools in more deprived areas were more likely to be allowed to participate in independent outdoor activities such as climbing trees (OR: 1.97; $p < 0.001$) and going to the playground (OR: 2.25; $p = 0.001$) but that there were no differences with regard to 'play'. A greater proportion of children from working and middle class backgrounds played outside (Thomson & Philo, 2004). Ziviani et al. (2008) reported that 6-7 year olds from lower SES neighbourhoods spent significantly more time playing in backyards and in neighbourhoods close to home than high SES counterparts, however the effects of potential confounders were not controlled. In addition, children aged 8-11 years from low/mixed class areas were more likely to be 'outdoor children', while middle and high SES children were more likely to be involved in organised activities (Valentine & McKendrick, 1997). In contrast, Karsten (2005) reported that children from lower class migrant backgrounds were typically more often 'indoor children'; alluding to factors such as safety and neighbourhood type.

Personal preferences emerged as a potential negative relationship with participation in outdoor play with some children preferring indoor activities such as television and computer games (Veitch et al., 2006; Veitch et al., 2007), as shown by the following quotes:

> 'He's got other things he prefers to do. If I let him, he'd watch TV all the time.' Parent of boy aged 10, mid SES (Veitch et al., 2006).

> 'I'd rather play the x-box.' Boy, aged 7, low SES (Veitch et al., 2007).

'Under most circumstances he would not choose to play outdoors…. It is not his preference, even on a nice day, to be outdoors.' Parent of boy aged 10, high SES (Veitch et al., 2006).

Interestingly, Thomson and Philo (2004) reported that while a similar proportion of boys and girls usually played outside, 'playing' indoors with computer games was more common amongst boys (22% vs. 12%). In contrast, some children are motivated to engage in active play to socialise, prevent boredom and to feel healthy (Brockman et al., 2011b). Children aged 10-12 from the UK and Australia also conveyed that a major motivation for active play was freedom from adult rules and structure (Brockman et al., 2011b; Veitch et al., 2007):

'We all want to be able to make sure we can do sometimes what we want – not what adults tell us to do.' Boy, high deprivation (Brockman et al., 2011b).

In longitudinal work, compared to those with low outdoor tendency, 10-12 year old boys with high outdoor tendency spent more minutes outside per week (beta = 123.2, $p < 0.01$), while for 10-12 year old girls medium outdoor tendency resulted in most time outdoors (beta = 200.4, $p < 0.05$). However in the same study the opposite was also true: children with high indoor tendency spent significantly less time outdoors over five years (Cleland et al., 2010). Being a child that prefers not to engage in physical activity was associated with less play in the yard location than other children on weekends (Veitch et al., 2010).

Table 3.4 *Summary of evidence relating to intrapersonal factors.*

| Intrapersonal factors | Study number(s) | Summary of evidence |
|---|---|---|
| Sex | 1, 2, 3, 5, 9, 10, 12, 26, 28, 29, 30, 36 | Males engage is more outdoor play than females. |
| Age | 1, 2, 3, 5, 9, 10, 28, 30, 36, 38 | Younger age related to more outdoor play. |
| Neighbourhood deprivation | 1, 24, 28, 30, 32, 33, 42 | Evidence suggests children from more deprived areas engage in more outdoor play. |
| Parental education | 1, 2, 5, 25, 37, 38 | Children whose parents attain higher education level engage in less outdoor play. |
| Personal preference | 8, 10, 32, 34, 35, 37 | Children who prefer indoor activities engage in less outdoor play. |
| White ethnicity | 3, 23, 25 | White children engage in more outdoor play than non-whites. |
| Body mass index | 3, 9, 28 | Evidence is mixed. |
| Parental work status | 25, 38 | Evidence is mixed. |
| Household income | 17, 25 | Evidence suggests no relationship. |
| Pubertal status | 28 | Evidence suggests no relationship. |
| Health status | 25 | Evidence suggests no relationship. |

*Note*: Study numbers correspond with those presented in Table 3.3.

### 3.4.3 Social-cultural factors.

Social-cultural factors have been sub-categorised as: 1) home/family situation 2) safety and crime; 3) parents' rules and attitudes; and 4) social cohesion and norms. Findings are summarised in Table 3.5.

#### *3.4.3.1 Home/family situation.*

Evidence regarding the relationship between a child's home/family situation and outdoor play did not reveal any strong trends. Two studies reported no relationship between marital status and play (Kimbro et al., 2011; Wen et al., 2009). However, qualitative evidence suggests that lone parents often had 'outdoor children' with greater freedom because they did not have a partner to share the burden of supervision (Valentine & McKendrick, 1997). Conversely, having no adults at home to supervise play resulted in 34.0 and 46.9 fewer minutes outdoors per week for 10-12 year old girls and boys respectively (Cleland et al., 2010). Similarly, qualitative work also revealed that after school child care arrangements were used by busy single parents and two-parent households were both adults worked full time. These arrangements led to reduced opportunities for outdoor play (Witten et al., 2013). Number of siblings was unrelated to play (Cleland et al., 2010; Veitch et al., 2010; Wen et al., 2009), however number of younger siblings was associated with play amongst adolescents (Bringolf-Isler et al., 2010). Dog ownership (Cleland et al., 2010), birth order (Prezza et al., 2001), having older siblings and number of residents in the home (Kimbro et al., 2011) were not associated with play. This finding conflicts with qualitative work which suggested that smaller family size meant that older siblings couldn't be employed by parents to supervise younger children's play and provide 'safety in numbers' (Witten et al., 2013).

#### ***3.4.3.2 Safety and crime.***

Parental perceptions of safety were investigated in six quantitative studies. Aarts et al. (2010) found that parental perceptions of safety resulted in small but significant gains (1-2%) in minutes of outdoor play amongst 4-6 year old children in The Netherlands. Parental perception of a safer neighbourhood meant that their child was more likely (OR: 1.28; $p$ = 0.05) to report spending more than 30 minutes outdoors playing per day (Wen et al., 2009). Odds for playing in the street or court were also greater (OR: 6.01 [weekends], 6.46 [weekdays]; $p$ = 0.001) if parents believed this was safe, but safety had no bearing on playing in the yard or in the park/playground (Veitch et al., 2010). For inner city children, play was negatively correlated ($r = -0.18$, $p < 0.05$) with concerns about neighbourhood safety (Weir et al., 2006). Two studies indicated that parents were not afraid to allow their children to play outside due to safety fears (Kimbro et al., 2011) or stranger danger (Veitch et al., 2010).

Children's perceptions of safety have rarely been investigated with regard to play. Hispanic adolescent females' (but not males') perception of neighbourhood safety was positively related (beta = 0.223; $p < 0.021$) to bouts of outdoor play (Gomez et al., 2004), however in another study no association was found (Page et al., 2010). On the other hand the same study found that nuisance (child perceptions of noise, crime, bullying) almost halved the odds (OR; 0.56; $p < 0.002$) that girls played outside every day (Page et al., 2010).

With specific regard to crime rather than safety as a whole, Bringolf-Isler et al. (2010) reported that parents who perceived crime as a problem had children who recorded on average 34.1 fewer ($p < 0.01$) minutes of outdoor play per day. This was the case for primary school children (aged 6-10 years), but not adolescents (aged 13-14 years). Two further investigations reported no association between play and parental perceptions of crime (Prezza et al., 2001; Veitch et al., 2010). After adjusting for child perceptions of neighbourhood safety, income and distance to nearest play area, objectively recorded crime rate was negatively (beta = -0.340; $p < 0.001$) associated with outdoor play for Hispanic females (Gomez et al., 2004). Parents were less likely to allow outdoor play as worries increased regarding over crime, witnessing violence, being a victim of violence, gangs, weapons and drugs (Kalish et al., 2010).

Themes related to safety/crime were the most commonly reported social-cultural factors in the qualitative studies. Children reported that rules and restrictions were likely due to parental fears of strangers and older children, or traffic and neighbourhood safety (Brockman et al., 2011b). This was reflected in a parental interview study in Australia which cited safety concerns as the most frequently reported factor related to children's play. Specific safety concerns included: strangers, teenagers, gangs and road traffic en route to places to play (Veitch et al., 2006):

'My main concerns regarding park use by my child are strangers, syringes, and main roads on the way there.' Parent of boy aged 9, low SES (Veitch et al., 2006).

Similarly, Jago et al. (2009) reported parental perceptions of safety to be the most reported barrier to children's independent physical activities, with traffic and strangers being primary concerns. Karsten (2005) reported that 'indoor children' typically had parents who viewed the street as unsafe, in particular due to older children. It has also been reported that parents are not gripped by paranoia, but feel tension between the fear of attack by strangers and recognition of the damage of restriction on social and physical development (Jenkins, 2006; O'Brien & Smith, 2002). The presence of older children was also raised in focus groups as a barrier by both parents and children, particularly for those from lower SES groups (Jago et al., 2009; Thomson & Philo, 2004; Veitch et al., 2006; Veitch et al., 2007) and was reported by some children to be spatially restrictive, i.e. there were some parts of town children felt unable to visit due to rival gangs (Thomson & Philo, 2004). This spatial restriction was also reported by mothers of black girls from deprived areas in the USA. In this study, perceptions of unpredictable violence and anti-social behaviour such as drug use by neighbours were so negative that parents indicated that outdoor play had to be supervised and took place outwith the local area (Dias & Whitaker, 2013). These difficulties are illustrated by the following series of quotations:

'A lot of teenagers use the park as a place to hang out and they're drinking and swearing and all that. Quite openly drinking and they don't even bother to hide it.' Parent of girl aged 10, low SES (Veitch et al., 2006).

'Well there's some like, really older girls down my road and they sort of like walk up and hang around by my house so, kind of stops me cos they would like come up and sort of like pick on you, so that's why I don't like go out.' Female, high deprivation (Brockman et al., 2011b).

'At around 5pm there's like a gang. You don't want to go there. They all sit down and they're all drinking and stuff.' Boy aged 11, low SES (Veitch et al., 2007).

'Me and my friends get in trouble from teenagers because once they invaded our gang……' Boy, high deprivation (Thomson & Philo, 2004).

Interestingly, for some, fears about other children were more likely to restrict their behaviour than parental rules (Brockman et al., 2011b; Thomson & Philo, 2004), and those from a low SES area suggested that safety from teenagers was more important than the condition of play facilities (Veitch et al., 2007).

For primary school children, parental perception that volume of traffic was a problem resulted in 24.4 fewer ($p < 0.005$) minutes of outdoor play per day (Bringolf-Isler et al., 2010), and reduced the chances ($p < 0.0001$) that children aged 5 to 7 would be allowed to play outdoors (Kalish et al., 2010). Child perception of traffic safety increased likelihood or playing every day (OR: 1.63; $p < 0.008$) for girls but not boys (Page et al., 2010). Two further studies reported parental perception of traffic was unrelated to outdoor play (Aarts et al., 2010; Prezza et al., 2001), while objectively measured traffic volume and speed also showed no association (Aarts et al., 2010). In qualitative studies, traffic was seen as 'an enormous risk' and a reason for restricting children's outdoor play (O'Brien & Smith, 2002). Both parents and children indicated use of public space was often restricted because children had to cross busy roads (Veitch et al., 2006; Veitch et al., 2007):

'Well X reserve is only down the road, it would only be a 5-10 minute walk, but it's not safe for them as there are busy road to cross. My sister lives next to a park. It's a little one but their kids go there all the time coz it's so close, and if we were in that situation I would, but we don't have that situation.' Parent of boy aged 10, mid SES (Veitch et al., 2006).

The relationship between perceptions of traffic as a hazard and outdoor play appeared to be cyclical. One study reported that parents were more likely to restrict outdoor play because of traffic, but then contribute to the traffic flow by transporting their child to school and to organised sports and exercise opportunities (Witten et al., 2013):

'So it's more convenient for us to drop them off…So we're actually adding to the traffic flow' Parent, primary school child (Witten et al., 2013).

#### *3.4.3.3 Parents' rules and attitudes.*

Independent mobility can be defined in terms of territorial range (geographical distance from home that a child can wander), the 'license' to move around outside the home unsupervised, or by measuring actual mobility in a certain period of time (Kytta, 2004). Independent mobility was strongly positively associated with play and time outdoors after adjustment for confounding variables (Page et al., 2010; Prezza et al., 2001; Wen et al., 2009). For example, Wen et al. (2009) reported that compared to those that were 'never' granted independence, children who were 'mostly' allowed independence were on average 2.56 times more likely ($p < 0.001$) to record 30 minutes of self-reported outdoor play per day. One study indicated that the presence of rules was not associated with outdoor play (Aarts et al., 2010), although the exact nature of the rules was not reported. Qualitative studies suggest that these rules often restrict play to close to home or when supervised by an adult:

'Basically she can go out the front on her scooter or on her bike as long as I can see her, that means she's got very restricted parameters.' Mother, low SES school (Jago et al., 2009).

'If they go to the local park then there's usually an adult with them.' Mother, middle SES school (Jago et al., 2009).

Qualitative studies also revealed differences in independent mobility by age and sex. Males reported spending more time outdoors playing in greenspace and streets with friends compared to females who played closer to the home, often with family members (Brockman et al., 2011a):

'I play on the community centre field'. Boy, high SES (Brockman et al., 2011a).

'I …go out in the garden …that's basically all.' Female, middle/high SES (Brockman et al., 2011a).

For some, often younger children, limited independent mobility was a major barrier to participation in outdoor play, especially if parents were unable to supervise them (Veitch et al., 2006; Veitch et al., 2007), as exemplified by the following remarks:

'I can't go the park because my mum says she's had a long tiring day at work and she can't take us.' Girl aged 9, low SES (Veitch et al., 2007).

'We can get to parks but it's having the spare time to get there because she has to go with me. I wouldn't let her go on her own.' Parent of girl aged 7, mid SES (Veitch et al., 2006).

In contrast older children were more independently mobile (Veitch et al., 2006), with the transition from primary school to secondary school marking the point at which greater license was afforded (Jago et al., 2009).

Parents' attitudes towards active free play appeared to be influential. For example, children of parents with positive attitudes were reported to participate in 32-75% more outdoor play varying by age and sex (Aarts et al., 2010), while being in a family that goes to the park increased likelihood that children played in the park on at least two week-days and one weekend-day (Veitch et al., 2010). Compared to low parental encouragement, high parental encouragement was a significant predictor of minutes outdoors for 5-6 year old (beta = 234.0; $p < 0.05$) and 10-12 year old (beta = 151.4; $p < 0.01$) girls (Cleland et al., 2010). Hammond et al. (2011) reported weak but statistically significant correlations between daily hours of outdoor free play and: positive parental attitudes towards children opening time outdoors ($r = 0.17$, $p < 0.05$), positive parental attitudes towards nature ($r = 0.22$, $p < 0.01$).

Differences in parental support appear to exist between SES groups. For example, a child focus group conducted in the UK reported that children attending a school in a low SES were verbally encouraged to engage in outdoor play, while those from middle/upper class schools received the necessary financial and logistical support to engage in more organised activities (Brockman et al., 2009):

‘My dad’s always telling me to go out and do something.’ Female, low SES (Brockman et al., 2009).

‘My mum says to get off the x-box and go and play tennis or something.’ Female, low SES (Brockman et al., 2009).

‘My parents do all they can to persuade me… to do physical activities and they take me to and from if needed.’ Female, middle/high SES (Brockman et al., 2009)

#### *3.4.3.4 Social cohesion and norms.*

Parental perceptions of neighbourhood social cohesion and relations were related to more outdoor play for children of both sexes. For example Prezza et al. (2001) reported that neighbourhood relations were positively associated with frequency of play with peers (beta = 0.142; $p < 0.05$), while Aarts et al. (2010) and Kimbro et al. (2011) reported small but significant increases (1-2%) in minutes of outdoor play per week and hours of outdoor play per day respectively. Relationships between parental perceptions of social norms and children’s play were explored in four qualitative studies. Some parents found allowing children to play in the street a convenient option for free play, however others strongly disapproved of children playing outside (Veitch et al., 2006):

‘I’ve got neighbours that let their kids play on the road and it’s disgraceful.’ Parent of boy aged 6, low SES (Veitch et al., 2006).

Social norms differed by SES, with parents from low SES groups experiencing pressures to allow independence, while parents from higher SES groups experienced pressures to restrict outdoor play (Valentine & McKendrick, 1997). Furthermore these authors suggested that the social norm for children’s play to be controlled in favour of more organised activities creates suspicion of those children who are permitted to go outside alone, while others report that limited license afforded to other children  as a barrier often cited by parents (Jago et al., 2009) and children alike:

‘Most of his friends don’t live as close as I would like for him to be able to go wandering around the streets on his own yet.’ Mother, middle SES school (Jago et al., 2009).

A qualitative study revealed that this normalisation of indoor play may be exacerbated in central urban areas where there is a perceived lack of play spaces and where the street is deemed too dangerous (Ergler et al., 2013). In addition to neighbourhood type, Ergler et al. (2013) reported that social norms for outdoor play can also differ by season with greater restrictions imposed during winter.

Quantitative data support the idea that it is important for children to have someone to play with. For 8-9 year olds in Australia, parental report of their child having friends in the neighbourhood was positively associated with playing in the street, however lots of other children being in the street was not related to play in any location (Veitch et al., 2010). This may be because ‘other children’ could include both friends and those that may be a safety concern.

Child perceptions that there were other children to play with increased likelihood (OR: 1.53 [girls], 1.63 [boys]; $p$ <0.05) of playing outside every day (Page et al., 2010). Similarly, Bringolf Isler et al. (2010) reported that children who lived close to their friends spent more time playing vigorously outdoors compared to those who could not reach their friends on their own (parental report of 101 vs. 81 minutes per day; $p$ = 0.05). Social opportunities were a predictor (beta = 169.7; p < 0.05) of minutes outdoors per week but only for 5-6 year old boys (Cleland et al., 2010), and friend’s participation was more important for unstructured than structured activity (Spink et al., 2006). Qualitative data also suggest children were more likely to play outside in the street or park if they had friends nearby (Karsten, 2005; Veitch et al., 2006; Veitch et al., 2007), while not having friends nearby and lack of ‘community connectedness’ could restrict independent physical activity (Curtis et al., 2012; Jago et al., 2009):

'I wouldn't let her go to the park on her own…I just tend to think there's more safety in numbers.' Mother, low SES school (Jago et al., 2009).

This problem was also summed up succinctly by one boy when asked why he didn't like going to the park:

'Because there's no one to play with. If there were more kids there I would want to go more often.' Boy age 7-8, mid SES (Veitch et al., 2007).

The need for community connectedness, and particularly links between parents was demonstrated by parents whose children did play often with other children, but only with prior organisation and collaboration between families (O'Brien & Smith, 2002). This lack of neighbourhood networks between children and parents was cited as a downstream effect parents' busier working lives and children attending schools further away from home (Witten et al., 2013). Karsten (2005) reported that 'outdoor children' were able to meet other children, and that this was facilitated by the homogeneity of the local social group and strong social networks.

Table 3.5 *Summary of evidence relating to social-cultural factors.*

| Social-cultural factors | Study number(s) | Summary of evidence |
|---|---|---|
| Parents' perceptions of safety | 1, 14, 21, 22, 24, 25, 27, 32, 34, 38, 39 | Children whose parents perceive greater safety engage in more outdoor play. |
| Other children to play with | 4, 5, 21, 24, 28, 31, 34, 35, 37 | The availability of child companions is related to more outdoor play. |
| Traffic safety | 1, 5, 23, 27, 28, 29, 34, 35, 40 | Parental perceptions of greater traffic safety are related to more outdoor play. |
| Independent mobility | 7, 21, 28, 29, 34, 35, 38 | Children afforded greater independent mobility engage in more outdoor play. |
| Neighbourhood social cohesion | 1, 13, 25, 27, 29, 40 | Those living in neighbourhoods with greater social cohesion and community connectedness engage in more outdoor play. |
| Social norms | 21, 28, 31, 33, 34 | Evidence suggests social norms are influential and may differ by SES. |
| Parents' attitudes to outdoor play | 1, 6, 19, 22, 37 | Positive attitudes and encouragement from adults are related to more outdoor play. |
| Child's perceptions of safety | 8, 17, 28, 32, 35 | Children's perceptions of greater safety are related to outdoor play. |
| Social norms | 21, 28, 31, 33, 34 | The social norm for outdoor play encourages participation and this appears to vary by SES, neighbourhood and season. |
| Objectively recorded crime rate | 17 | Crime rate is negatively associated with children's outdoor play. |
| Number of younger siblings | 5 | Children with younger siblings engage in more outdoor play |
| Parental perceptions of crime | 5, 23, 29, 37 | Evidence is mixed. |
| Supervision | 9, 10, 21, 40 | Evidence is mixed. |
| Parents' marital status | 25, 33, 38 | Evidence is mixed. |
| Number of older siblings | 25, 40 | Evidence is mixed. |

| Social-cultural factors | Study number(s) | Summary of evidence |
|---|---|---|
| Number of siblings | 10, 37, 38 | Evidence suggests no relationship. |
| Birth order | 29 | Evidence suggests no relationship. |
| Number of residents | 25 | Evidence suggests no relationship. |
| Dog ownership | 10 | Evidence suggests no relationship. |

*Note*: Study numbers correspond with those presented in Table 3.3.

### 3.4.4 Physical-environmental factors.

Physical-environmental factors have been sub-categorised here as: 1) home characteristics; 2) neighbourhood characteristics; 3) facilities/amenities; 4) aesthetics/physical disorder; and 5) natural environment. Findings are summarised in Table 3.6.

#### *3.4.4.1 Home characteristics.*

Evidence related to the availability of gardens or yards was equivocal. Presence or size of a garden (Veitch et al., 2010) or courtyard (Prezza et al., 2001) at home was not associated with outdoor play. Another study found that non availability of both a garden and a park resulted in 39.7 fewer ($p < 0.05$) minutes of outdoor play per day compared to primary school children who had access to both (Bringolf-Isler et al., 2010). Absence of a garden was related to 25% fewer ($p < 0.05$) minutes of outdoor play per week for girls aged 7-9 years, 13% more ($p < 0.05$) minutes for girls aged 4-6, and was not associated with outdoor play in boys of all ages or adolescent girls (Aarts et al., 2010). One qualitative study reported that mothers of black girls in a deprived neighbourhood cited homes with private yards as one potential mechanism to encourage outdoor play (Dias & Whitaker, 2013). Physical activity equipment at home was not associated with time outdoors (Cleland et al., 2010), and play space was not associated with play (Page et al., 2010). In contrast, children who had electronic devices such as televisions or computers were reported to engage in 4-15% more ($p < 0.05$) minutes of outdoor play per week (Aarts et al., 2010). However parents also indicated that ‘electronic bedrooms’ and time absorbed in virtual entertainment was at the cost of outdoor play (Witten et al., 2013). Research concerning type of residence has produced mixed findings. Kimbro et al. (2011) reported that compared to living in a house, living in an apartment was associated with 12% fewer hours of weekly outdoor play ($p < 0.05$). Another study found that associations varied greatly dependent on age/sex subgroups (Aarts et al., 2010).

#### *3.4.4.2 Urbanicity, neighbourhood form and street design.*

Living in older or newer parts of the city had no association with outdoor play (Prezza et al., 2001). Compared to those living in the city centre, parents living in a suburban area reported that their children engaged in more play; however confounders such as SES were not controlled in analyses (Weir et al., 2006). In a multivariate study which defined neighbourhood type using postcode, living in the city centre was negatively associated with outdoor play for boys aged 7-9 years, while living in a city green area was positively associated with outdoor play for girls aged 4-6 years (Aarts et al., 2010). Another multivariate study from Italy found that rural children engaged in approximately 60 minutes more parental reported outdoor physical activity per day than suburban and urban children (Donatiello et al., 2013). In contrast, a much smaller UK study using GPS and accelerometer methods reported approximately 30 minutes more outdoor MVPA in suburban compared with rural children (Collins et al., 2012).

Aspects of neighbourhood structure and connectivity have also been investigated. A study using Geographic Information Systems (GIS) to assess environmental attributes reported that main street density, population density and building density within 100 m of the residence were negatively associated with outdoor play, while side-street and small route density had no association (Bringolf-Isler et al., 2010). Another study using independent observation of the environment reported that residential density and land use mix (proportion of enterprises to residences) were unrelated to outdoor play (Aarts et al., 2012). Using behavioural mapping and GIS, Holt et al. (2008) categorised the walkability of neighbourhoods based on residential density, mixed land use and connectivity of streets. The authors demonstrated that younger children (aged 6-8 years) in a low walkability neighbourhood depicted more outdoor play in the home/yard environment than older children (aged 11-12 years), but that in a high walkability neighbourhood, older children depicted more outdoor play. Supporting this finding, amongst 8-9 year olds, living in a cul-de-sac meant that children were approximately four times more likely ($p < 0.01$) to play outdoors in the street on at least two week-days and one weekend-day (Veitch et al., 2010), while diversity of routes was related to outdoor play amongst 10-12 year old boys (relative risk [RR] = 1.08; $p < 0.05$) and 7-9 year old girls (RR = 1.03; $p < 0.05$) respectively (Aarts et al., 2010).

Qualitative work supports the idea that a cul-de-sac/court neighbourhood design may be beneficial, for example males from a low SES school indicated that living in a cul-de-sac facilitated their active play (Brockman et al., 2011b). The area immediately around the home, including the drive way and street, were indicated by children's photographs as important outdoor play locations (Beets et al., 2011). In another study, parents who perceived their street to be safe were more likely to allow outdoor play, and all parents who lived in courts or cul-de-sacs reported that their child engaged regularly in this behaviour (Veitch et al., 2006).

'I guess because we've got the court, it's not overly important to have the parks.' Parent of boy aged 10, mid SES (Veitch et al., 2006).

Parents viewed a major advantage of a cul-de-sac as being the 'strong community oriented network between neighbours', and the type of immediate environment was also reported to mediate social norms with regard to outdoor play (Veitch et al., 2006).

#### ***3.4.4.3 Facilities/amenities.***

Relationships between outdoor play and facilities/amenities were investigated in seven quantitative studies and generally showed no association. Presence and quality of greenspace, presence and quality of water, distance to facilities, and access to facilities were not associated with outdoor play (Aarts et al., 2012; Aarts et al., 2010; Page et al., 2010). Use of a neighbour's garden (19.2 minutes; $p < 0.05$) or fields/woods further than 500 m away (22.5 minutes; $p < 0.05$) were both related to more vigorous outdoor play (Bringolf-Isler et al., 2010). Parental satisfaction with facilities, parks or greenspace was not associated with outdoor play (Aarts et al., 2010; Veitch et al., 2010). Objectively measured distance to play area or parks was negatively associated (beta = -0.317; $p$ = 0.006) with outdoor physical activities amongst Hispanic adolescent boys but not girls (Gomez et al., 2004). Parental perception of park proximity had no association with outdoor play in another study (Prezza et al., 2001). Number of formal outdoor play facilities was negatively associated with outdoor play, but the quality of these spaces had no association (Aarts et al., 2012).

Children of both sexes reported greenspace was a location frequently used for play (Brockman et al., 2011b). However, in support of the quantitative evidence above, children did not report playing in adult designed play spaces (Brockman et al., 2011a). Parents, especially those from low SES areas, voiced concerns of a lack of specifically designed and appropriate play areas for children (Jago et al., 2009; Valentine & McKendrick, 1997), and this was a particular problem for older children (Veitch et al., 2006; Veitch et al., 2007):

‘Well not having a kind of immediately accessible space where you can either be in a group or do your own thing affects their [activity] choices.’ Mother, low SES school (Jago et al., 2009).

‘The parks are pretty boring ‘cos it’s all baby stuff in there.’ Girl aged 11, low SES (Veitch et al., 2007).

‘I guess there’s not enough equipment to interest older children. I don’t mean teenagers but at ten years, X has to come with us, as he’s not old enough to be left at home. So every time you want to go it’s an argument because he’s just not that interested. Whereas a couple of years ago they were begging me to go.’ Parent of boy aged 10, high SES (Veitch et al., 2006).

Instead of purpose built facilities children appear to prefer informal spaces, particularly streets and cul-de-sacs (Thomson & Philo, 2004). Children also reported that the condition of play areas or equipment was not important, so long as they had somewhere to play independently with their friends away from adults and teenagers (Veitch et al., 2007).

#### *3.4.4.4 Aesthetics/physical disorder.*

Parental perceptions of unoccupied homes in the neighbourhood were positively associated with outdoor play for boys aged 10-12 (Aarts et al., 2010), while objective observation revealed no association (Aarts et al., 2012). In the same study, presence of dog waste was positively associated with outdoor play for girls aged 4-6 years. Aesthetics, presence of trash and quality of sidewalks/bike lanes were not associated with outdoor play (Aarts et al., 2012; Aarts et al., 2010; Page et al., 2010). Physical disorder was positively associated with outdoor play amongst five year olds (Kimbro et al., 2011).

#### *3.4.4.5 Seasonality.*

Seven studies investigated seasonality. Time outdoors as measured by GPS (49.7 vs. 37.8 minutes per day; $p < 0.01$) was greater during summer months than during winter months (Cooper et al., 2010). Parents in the USA who were interviewed during a cold winter reported significantly less child outdoor play (Kimbro et al., 2011). Daylight hours were not associated with outdoor play in one UK study (Page et al., 2010), however another reported that greater outdoor play was responsible for up to 50% of the greater physical activity occurring on longer days (Goodman et al., 2012). Structured sports and active travel were less affected by day length, and wind, rainfall and cloud had little effect on any physically active behaviour (Goodman et al., 2012). Parental perceptions of the effect of dark and cold during winter and heat during summer in Australia were not related to outdoor play (Cleland et al., 2010). However, children of both sexes from the UK reported adverse weather to be a barrier to active play in one qualitative study (Brockman et al., 2011b). Finally, one study compared outdoor physical activity in USA towns which had been treated or untreated for prevalence of day-biting mosquitos. Children self-reported more outdoor activity in the town which had been treated compared with children living in the town which had not (Worobey et al., 2013).

Table 3.6 *Summary of evidence relating to physical-environmental factors.*

| Physical-environmental factors | Study number(s) | Summary of evidence |
|---|---|---|
| Walkability | 1, 2, 5, 8, 20, 34, 37 | Cul-de-sacs appear to facilitate primary school children's outdoor play. Adolescents may benefit from walkable neighbourhoods. |
| Satisfaction with play areas | 1, 4, 7, 8, 21, 32, 33, 34, 35, 37 | Adults and (especially older) children perceive a lack of appropriate play spaces. Informal spaces such as streets are often preferred. |
| Natural environment | 8, 12, 18, 25, 28 | Adverse weather conditions and light may be a barrier to outdoor play for children in some locations. |
| Urban/suburban | 1, 39 | City centre children appear to engage in less outdoor play than suburban children. |
| Number of play areas | 2 | Number of play areas related to less outdoor play. |
| Presence of day-biting mosquitos | 41 | Presence of day-biting mosquitos associated with less outdoor play. |
| Aesthetics/ physical disorder | 1, 2, 25, 28 | Evidence is mixed. |
| Presence of home garden/yard | 1, 5, 14, 29, 37 | Evidence is mixed. |
| Proximity of play areas | 17, 29 | Evidence is mixed. |
| Urban/rural | 11, 15 | Evidence is mixed. |
| Presence of electronic devices | 1, 40 | Evidence is mixed. |
| Residence type | 1, 25 | Evidence is mixed. |
| Presence of physical activity equipment | 10 | Evidence suggests no relationship. |
| Old/new area of city | 29 | Evidence suggests no relationship. |
| Presence/quality of Green/blue space | 1, 2, 5, 28 | Evidence suggests no relationship. |

*Note*: Study numbers correspond with those presented in Table 3.3.

### 3.5 Discussion

This review represents the first attempt to draw together the quantitative and qualitative literature reporting correlates and determinants of children's physical activity during outdoor play. The review provides a much needed summary of current understanding of the factors which are associated with this domain of physical activity, which to date has received comparatively little research attention. The following section provides a discussion of this evidence and a critique of the way outdoor play has been defined and measured. In doing so, important future directions for both intervention design and methodological research pertaining to outdoor play are highlighted. The key findings of this review are that parental perceptions of safety, independent mobility, neighbourhood social cohesion, having other children to play with, and cul-de-sac neighbourhood design have been found to be consistently related to greater outdoor play. In common with previous reviews of physical activity, many features of the social and physical environment are inconsistently associated with outdoor play or have seldom been investigated, and should therefore be the focus of further research. Relationships between some environmental factors and outdoor play differ by population subgroup; of particular importance are the moderating effects of sex, age, season and SES.

This review emphasises the importance of parents as key 'gatekeepers' to children's outdoor play (Veitch et al., 2006), and echoes the findings of a review of factors influencing children's trips to school (McMillan, 2005). Parents' control over outdoor play is likely expressed through regulation of their children's independent mobility. Previous work reports that parents are increasingly restricting children's independent mobility (Hillman, 2006; Hjorthol & Fyhri, 2009), and letting children play outdoors has perhaps even become a sign of being a neglectful parent (O'Brien, Jones, Sloan, & Rustin, 2000). The limited trend data suggest that today's children play outside less often, spend less time outdoors and are more restricted in their movement outside the home (Hillman et al., 1990; Pooley et al., 2005). Today's children have been labelled the 'backseat generation', who spend greater time indoors being sedentary, and upon leaving the home are ferried in cars to organised activities structured around adult lives (Karsten, 2005; Valentine & McKendrick, 1997). Studies of independent mobility report that boys and older children are afforded greater license (Carver, Timperio, Hesketh, & Crawford, 2010; Johansson, 2006; O'Brien et al., 2000) and are more likely to be permitted to engage in outdoor activities than girls and younger children (Soori, 2006). In particular, parents are reported to be more protective of girls due to perceived risk (Carver et al., 2010; Carver, Timperio, Hesketh, & Crawford, 2012; Hillman et al., 1990). Evidence presented here reflects this, indicating that boys play outdoors more than girls. Parental fears about strangers, crime and older children contribute towards decision making about independent mobility (Carver, Timperio, & Crawford, 2008; Prezza et al., 2001). This review indicates that these parental perceptions are consistently related to children's participation in outdoor play, a finding also echoed in the active travel literature (Panter et al., 2008; Timperio, Crawford, Telford, & Salmon, 2004). The threat of nuisance or bullying from older children has been frequently cited by both parents and children, and would appear to be a problem in particular need of attention, particularly for girls and children from low SES groups (Brockman et al., 2011b; Page et al., 2010; Veitch et al., 2007). Whilst the evidence is consistent in reporting these concerns as barriers, it may be the case that perceptions of safety are relative, i.e. what is considered safe by children (and parents) living in one neighbourhood may be quite different to those living in another. For example, those living in locations where gangs and more violent types of crime are commonplace may not identify the same threats as those living in areas where there are fewer gangs and antisocial behaviour. It is also possible that being in a gang encourages physical activity for those who are members. A generalised approach with regard to changing perceptions of safety may therefore be ineffective. Further work is required to understand the efficacy of a more targeted approach which addresses specific safety concerns in specific locations. Independent mobility may mediate relationships between features of the environment and children's outdoor play. While enhancing perceptions of safety may be a potential intervention strategy for promoting outdoor play, this may prove fruitless unless decisions about independent mobility are modified. Further research is required to understand how parents formulate these decisions, and to identify appropriate specific behavioural change techniques for use in interventions.

Outdoor play is an inexpensive form of physical activity which may be particularly important for children from low SES backgrounds (Humbert et al., 2006). Studies assessing neighbourhood SES suggest that those from more deprived areas engage in more outdoor play, are more independently mobile, and are often actively encouraged to go outside and play by their parents (Brockman et al., 2009; Soori & Bhopal, 2002; Valentine & McKendrick, 1997; Ziviani et al., 2008). In contrast, evidence of an association between household SES and participation in play is inconsistent. This is perhaps unsurprising given the variety of markers used in available studies. Socio-economic status is a broad concept; at present it is unclear which particular aspects of SES are associated with outdoor play, or the specific manner in which these influences are exerted (Shavers, 2007). Nonetheless, this review suggests that aspects of SES which may impact parent's ability to supervise or encourage play such as marital status or maternal employment may be more influential than those relating to wealth or income. For children, independence from adult rules and structure is an important aspect of play, however some work reports that many children rely on parents to supervise or encourage their physical activity (Cleland et al., 2010; Jago et al., 2009). The availability of supervision is vital for children whose parents also limit their independent mobility, and supervision may be unavailable if both parents are working during the 'critical hours' for physical activity immediately following school (Cleland et al., 2008; O'Brien et al., 2000). A recent review has shown that social support from family, particularly as co-participators, is consistently and positively associated with physical activity in adolescence (Mendonca, Cheng, Melo, & de Farias Junior, 2014). Understanding the effect of supervised and unsupervised time for different groups may be important, particularly for those at the transition from primary to secondary school when greater independence tends to be established (Jago et al., 2009). Furthermore, given the importance of other children and social interactions for independent physical activity, it may be important to assess who children spend their free time with and to what extent these social contexts are supportive of MVPA.

The current evidence suggests SES has a complex role in determining the social norms governing independent mobility and the types of physical activity available to youth. Children from higher SES groups may experience barriers to participation due to maternal social norms to restrict outdoor time and independent mobility (Valentine & McKendrick, 1997). Some children are able to compensate for this missed physical activity with structured sport and exercise, however for others this may not be feasible due to financial or time barriers (Kantomaa, Tammelin, Nayha, & Taanila, 2007). Furthermore, there are some benefits of outdoor play which may not be obtainable during more institutionalised activities (Burdette & Whitaker, 2005b; Valentine & McKendrick, 1997). A subgroup of children with limited access to both play and more structured activities may struggle to accumulate physical activity during leisure-time.

It may be particularly important to better understand the physical environment of outdoor play, especially considering that many children seem to prefer informal spaces such as greenspace or sidewalks over purpose built play areas. Some counter-intuitive findings such as the presence of unoccupied homes and physical disorder being related to more outdoor play also support the notion that outdoor play occurs in unexpected locations. The availability of facilities in neighbourhoods is often positively associated with aggregated measures of physical activity (Davison & Lawson, 2006), however this review indicates no relationship or even negative relationships between number/quality of play areas and outdoor play. These observations indicate insufficient understanding about the nature of outdoor play and where it takes place, and reinforces the importance of studying context-specific behaviours and correlates (Giles-Corti, Timperio, Bull, & Pikora, 2005b). Outdoor play does not seem to necessarily occur in expected locations, especially those which are adult designed and suitable only for very young age groups (Brockman et al., 2011a). Instead, informal play spaces away from adult supervision and gangs appear to be favoured, with aesthetics or condition secondary concerns (Veitch et al., 2007). Alternatively, it may be that those children who rely more on outdoor play as a source of physical activity (rather than more structured activities) only have access to certain locations in perhaps more deprived neighbourhoods.

A cul-de-sac neighbourhood design appears to offer an informal play space supportive of physical activity. A supportive neighbourhood is one which has a combination of environmental attributes making it more attractive for physical activity (Jones et al., 2007). One key attribute of cul-de-sacs which makes them conducive to outdoor play is a sense of community between neighbours (Veitch et al., 2006). Evidence included here indicates social cohesion is consistently associated with outdoor play. Research not part of this review reports that social interaction and local friends contribute towards a sense of safety for both parents and children (Mikkelsen & Christensen, 2009; Valentine, 1997); while other work reports that neighbourhood relations are associated with greater independent mobility (Prezza et al., 2001). The cul-de-sac street design perhaps provides a location for children and parents to form strong social networks (Brockman et al., 2011b). On the other hand, it may be necessary for these networks to be in place before parents are willing to consider permitting outdoor play. A lack of other children to play with was a common barrier arising from the qualitative research.

There have been very few studies investigating outdoor play amongst children attending secondary school. This is perhaps because it is seen as an activity for primary school children. Younger children see lack of independent mobility as a significant barrier to outdoor play (Veitch et al., 2007); however older children who are typically granted greater independence engage in this behaviour less frequently. It is unclear how children spend their leisure-time and to what extent their behaviours are spent engaging in MVPA. It may be that older children engage in comparable unstructured behaviours that they do not identify as outdoor play. Alternatively it may be true that children become more inactive despite greater independence, or participate in more structured physical activity opportunities. Given that the meaning of play varies between children (Brockman et al., 2011a), and that most studies have used parental proxy-report measures, unstructured outdoor physical activity behaviours not identified as play may have gone unreported. Definitions of outdoor play also vary between studies and may relate to the researchers' or even parents' ideas about their own childhood play rather than the experiences of contemporary children. As described above, counter intuitive quantitative data and qualitative reports indicate a present misunderstanding of where and how 'outdoor play' takes place. Attempts have been made by Brockman et al. (2011a) to understand the meaning and nature of play, however further work is necessary. If children do not recognise the domains of physical activity ascribed to them, it is unlikely that interventions targeting those domains will be effective. From this review it is apparent that assumptions about outdoor leisure-time may not be appropriate for some children. Research is required to deconstruct children's leisure-time into its constituent components and characterise the type, context and intensity of children's behaviour.

The present review attempted to draw together evidence from studies using various definitions and measures of outdoor play. It has proven difficult to interpret and compare the findings of studies which on the surface investigate the same topic but in fact may be describing very different behaviours. The use of self- or proxy-report measures combined with possible confusion regarding the definition of outdoor play means that the intensity and contribution of this domain towards daily MVPA targets is unclear. For example, it is possible that amongst all age groups, sedentary behaviours such as computer games or chatting have been misreported as 'active' play (Aarts et al., 2010; Brockman et al., 2011a). Furthermore, outdoor play is thought to be sporadic, short lived and unmemorable (Bailey et al., 1995; Brockman et al., 2011a), attributes that complicate measurement using subjective reports (Kohl et al., 2000). The inconsistency of findings and possible misunderstanding surrounding outdoor play may be a methodological issue which could be aided by quantification using automated objective measures. Unfortunately this too is difficult because outdoor play recorded by measures such as accelerometry must still be distinguished from other forms of physical activity. Veitch et al. (2008) have used the specific definition of 'unstructured outdoor physical activity in children's leisure-time'. Working from this definition it may be possible to capture a fuller range of behaviours, in particular those of older children who may not identify with the label 'outdoor play'. Rather than assigning the domain label 'outdoor play' which carries many assumptions and may not always be appropriate, it could be more comprehensive and informative to partition children's leisure-time according to its contextual attributes, for example whether activities are structured or unstructured, indoors or outdoors.

Judged against preferred reporting items for systematics reviews (Moher et al., 2015), this chapter has a number of weaknesses. Firstly, because of the great variation in study design, definitions and measures of outdoor play, and the inclusion of qualitative data, a quantitative meta-analysis was not conducted. Instead, the synthesis and summaries of evidence provided for individual variables were based upon one researcher's subjective appraisal of the available evidence. Furthermore, the inclusion and exclusion of studies was not validated by a second investigator at the title, abstract or full-text screening stages. There was no formal evaluation of the quality of the studies included in the review, nor any evaluation of the risk of meta-biases such as publication bias or selective reporting within studies, which may have led to an overestimation of the importance of variables simply because they have been more often investigated.

### 3.5.1 Conclusions

Compared to the physical environment, relationships between the social-cultural environment and outdoor play are better understood. The present review suggests that parental perceptions of safety, neighbourhood social cohesion, having other children to play with, and living in a cul-de-sac are related to outdoor play, and that parents have a key role as 'gatekeepers' to this behaviour. Given that children's outdoor play is reported to be more institutionalised and independent mobility more restricted, further work is required to investigate these interrelated factors and explore whether manipulating these variables can help promote this physical activity in this domain. Consideration should be given to the moderating effects of sex, age, season, and SES. Prior to this however, it is necessary to address knowledge gaps relating to the type and context of children's leisure-time behaviour, as this review indicates that some of the assumptions about how children make use of outdoor environments may not hold true. Before intervention strategies can be formulated, it is necessary to better understand the indoor and outdoor contexts children encounter, and to what extent time is spent engaging in MVPA. This review indicates two themes linked to independent mobility that may be particularly important for children's physical activity:1) who children spend their indoor and outdoor leisure-time with; and 2) whether indoor and outdoor leisure-time is structured or unstructured.

**3.6 What Did This Chapter Contribute?**

- Parental perceptions of safety, neighbourhood social cohesion, having other children to play with, and living in a cul-de-sac are consistently related to outdoor play.
- Independent mobility is also an important correlate and parents have a key role as 'gatekeepers' to this behaviour.
- Relationships are often moderated by sex, age, season, and SES.
- The nature of children's outdoor time varies greatly and our understanding of how, where and with whom children spend their leisure-time may need to be re-evaluated.
- It is necessary to address knowledge gaps relating to the type and context of children's leisure-time physical activity, plus the extent to which time spent in different indoor and outdoor contexts contributes to MVPA recommendations.

# Chapter Four
# Aim, Research Questions and Methodology

## 4.1 Aim and Research Questions

Section 1.1 stated that the aim of this research was to 'develop greater understanding of the role of outdoor play as a potential intervention target to increase children's physical activity levels'. Consistent with current guidance (Craig et al., 2008), the review in Chapter Three was conducted to investigate the individual, social- and physical-environmental correlates and determinants of outdoor play and identify possible mechanisms of behaviour change. However, the review revealed several knowledge gaps and weaknesses in understanding that need to be addressed. Consequently, this section describes a revised aim of this thesis, plus three research questions which support that aim.

The findings of Chapter Three suggest that outdoor play is a complex domain of physical activity behaviour that has different meanings for different children. It is also a domain that has been variously defined and measured by researchers. In comparison to a domain such as physical education, it would appear to take many forms and would also appear to evolve with age, to such an extent that the label outdoor play may no longer be appropriate as children move into early adolescence. This evolution has clear implications for studies using self-report measures recording a behaviour which some children may not recognise. As such, 'outdoor play' physical activity is difficult to measure, and furthermore, there may be entire groups of complementary unstructured outdoor physical activities that are yet to be measured or explored.

This hypothesis is supported by the inconsistent and sometimes counter-intuitive relationships with environmental factors reported in Chapter Three. The evidence from qualitative studies also reveals a lack of understanding of how, where and with whom children make use of the outdoor environment during their leisure-time. It is widely acknowledged that being outdoors, rather than indoors, is important for physical activity; however there are very few studies examining the specific contexts children encounter when indoors and outdoors. In addition, a key weakness of much of the aforementioned research is that physical activity has not been measured objectively using methods such accelerometry, meaning that it is difficult to assess the intensity of time spent in specific indoor and outdoor contexts, or make recommendations as to whether intervention in these areas may contribute towards children meeting daily MVPA guidelines.

Developing greater awareness of how and why children obtain their physical activity in different contexts is important because these diverse behaviours are likely to have different health and social benefits, as well as different determinants (Caspersen et al., 1985; Giles-Corti & King, 2009). Consistent with an ecological approach to modifying health behaviours (Giles-Corti et al., 2005a; Sallis et al., 2008), context-specific data of this kind are necessary to guide future research and inform intervention strategies. For this purpose, it is proposed that two types of data are required: 1) within each day, the existing contributions of different contexts to children's total MVPA (i.e. the physical activity profile); and 2) within each context, the rate of accumulation of MVPA. Together, these data can provide indicators as to which contexts and behaviours should be targeted to have the greatest impact on daily physical activity at a population level.

Some consistent findings from Chapter Three offer guidance as to which particular contextual factors may have an important impact on physical activity occurring indoors and outdoors. Firstly, it was apparent that factors relating to who leisure-time was spent were associated with participation in physical activity (for example having other children to play with). Despite the apparent importance of having other children to play with, and concern that children's independent time outdoors is limited, no studies have investigated who children spend their indoor and outdoor time with or how much MVPA is recorded in these contexts. Secondly, the review highlighted potential restrictions in access to unstructured outdoor physical activity in favour of adult-led structured sport and exercise. Whilst parental safety fears and limited independent mobility were highlighted as barriers to outdoor play, the contributions of structured and unstructured leisure-time occurring indoors and outdoors toward total daily MVPA have never been examined. These two factors are both thematically linked to children's independent mobility, which is consistently and positively associated with aggregated measures of children's physical activity and time outdoors. Better understanding of how children make use of these indoor and outdoor contexts is particularly important for children at the transition from primary to secondary school as it is at approximately this age when independence being to develop.

### 4.1.1 Revised aim of the thesis.

Thus, rather than investigating the domain 'outdoor play' as initially stated in section 1.1, it is necessary to deconstruct children's leisure-time in order to accurately describe and quantify the context of their physical activity. In particular, the duration and intensity of time spent in different contexts and potential contributions toward guideline amounts of MVPA are unknown. It is therefore the revised aim of this research to develop greater understanding of the indoor and outdoor contexts of children's leisure-time physical activity. This aim is supported by the following three research questions:

1. Who do children spend their indoor and outdoor leisure-time with, and how does time spent in these contexts relate to after school MVPA?
2. Is it possible to use GPS signal-to-noise ratio data to discriminate indoor and outdoor physical activity locations?
3. Is children's indoor and outdoor leisure-time structured or unstructured, and how does time spent in these contexts relate to total daily MVPA?

In order to achieve this aim and answer these research questions, three studies have been conducted. These are reported in Chapters Five, Six and Seven. The first research question is addressed using previously collected data from the PEACH project and is presented in Chapter Five. The second research question is addressed in Chapter Six. Chapter Seven addresses the third research question and utilises new data collected from schools within the City of Edinburgh.

## 4.2 Methodological Approach

At described in section 2.3, measurement of physical activity is a complex task, and there are a large number of methods of assessment used for a variety of purposes within physical activity investigations. It is therefore important to explain the methods used and how this approach meets the specific demands of the research. This section sets out the methodological approach used to answer the research questions outlined in section 4.1.1. More specific details of the methods used in individual studies are described in Chapters Five, Six and Seven.

The aim and research questions detailed earlier in this chapter necessitate a method capable of:

- Differentiating the indoor and outdoor location of physical activity
- Recording contextual information such as who children are with or whether they are engaging in structured or unstructured forms of physical activity.
- Recording the variation in activity intensity over time for extended periods and with sufficient detail so that MVPA can be quantified and time matched to contextual data.

A key challenge to increasing our understanding of how children make use of the outdoor environment is how these behaviours are measured (Jones, Coombes, Griffin, & van Sluijs, 2009). No single measurement tool can fulfil the above criteria, thus it is very difficult to identify physical activity occurring within different contexts and locations (Cooper & Page, 2010). The studies reviewed in Chapter Three investigated outdoor play as specific behaviour, however all but one used subjective methods of assessment. These methods may not be appropriate for children's leisure-time physical activity, especially that which is sporadic, unplanned and less memorable such as unstructured outdoor play. The preference is therefore to use an objective method which records physical activity automatically at high frequency (short epoch). Accelerometry is the optimal method for assessing the temporal pattern and intensity of physical activity (Rowlands & Eston, 2007), but does not record any contextual information.

Recently researchers have recognised the potential of GPS data to describe individual behaviours and interactions with the physical environment (Cooper & Page, 2010). A GPS receiver allows the location of an individual to be tracked automatically and objectively at high frequency and over long periods. This technology has been used in mobile phones to investigate independent mobility in children (Mikkelsen & Christensen, 2009). However, it is the combination of GPS with accelerometer data which is perhaps most appealing to researchers. Time matching of these two separate datasets permits investigation of where, when and at what intensity physical activity occurs with little intrusion into children's normal daily routines (Davison & Lawson, 2006; Jones et al., 2009). The combination of accelerometer and GPS data has been used to investigate physical activity occurring in different land use types (Jones et al., 2009), assess the location and intensity of travel behaviours (Oliver, Badland, Mavoa, Duncan, & Duncan, 2010), and identify walking trips (Cho, Rodriguez, & Evenson, 2011). One simple but informative application of GPS data is to discern physical activity which occurs outdoors, as demonstrated by Cooper et al. (2010). Combining these instruments in this way offers an objective method to accurately record the pattern of indoor and outdoor physical activity.

Whilst the combination of GPS and accelerometer data is an informative tool for exploring the physical location of activity, there are still some contextual attributes that are challenging to capture objectively. Who children are with and whether they are engaging in structured or unstructured activities are examples of contextual information which can be collected using a diary or log. Accelerometer data have previously been augmented by subjective reports providing contextual data such as the type of activity (Bringolf-Isler et al., 2009; Goodman et al., 2012; Wickel & Eisenmann, 2007). Accelerometer data can also be categorised using time segments of the day, for example school start and finish times, after school club times or lunch and recess periods. This research shall therefore use a simple activity diary to enhance the objective data recorded by GPS and accelerometer. Although these three methods have been used in the same study previously (Mackett, Brown, Gong, Kitazawa, & Paskins, 2007), this is the first research to combine all three concurrently to provide a rich description of the source of children’s physical activity.

## 4.3 What Did This Chapter Contribute?

- This chapter has presented a refined aim of this thesis and set out three supporting research questions.
- Since no single measurement tool can satisfy the requirements of the research questions posed, this research shall use a combination of GPS receiver, accelerometer and diary methods to provide information about the intensity and contextual attributes of children's physical activity.

Chapter Five

# Who Children Spend Time with After School: Associations with Objectively Recorded Indoor and Outdoor Physical Activity


## 5.1 Abstract

At present little is known about who children spend their time with after school, how this relates to time spent indoors or outdoors and activity in these locations. This study aimed to quantify who children spend their time with when indoors or outdoors and associations with moderate to vigorous physical activity.

The study used data collected between September 2006 and July 2008 Participants were 427 children aged 10–11 years from Bristol, UK. Physical activity was recorded using an accelerometer (Actigraph GT1M) and matched to GPS receiver (Garmin Foretrex 201) data to differentiate indoor and outdoor location. Children self-reported who they spent time with after school until bed-time using a diary. These three sources of data were combined to create ten activity contexts. Time spent and MVPA were summarised for each context. Associations between time spent in the different contexts and MVPA were examined using multivariate linear regression adjusting for daylight, age, deprivation and standardised body mass index.

After school, children were most often with their mum/dad or alone, especially when indoors. When outdoors more time was spent with friends (girls: 32.4%; boys: 29.9%) than other people or alone. Regression analyses suggested hours outdoors with friends were positively associated with minutes of MVPA for girls (*b*-value [95% CI]: 17.4 [4.47, 30.24]) and boys (17.53 [2.76, 32.31]). Time spent alone was not associated with MVPA regardless of sex or indoor/outdoor location.

Time spent outdoors with other children is an important source of MVPA after school. Interventions to increase physical activity may benefit from fostering friendship groups and limiting the time children spend alone.

## 5.2 Introduction

Describing the value of different environmental and social settings for physical activity could inform context-specific interventions (Dunton, Liao, Intille, Wolch, & Pentz, 2011). Leisure-time is a key source of children's physical activity, especially during the 'critical window' immediately after school (Atkin et al., 2008). After school leisure-time may be spent alone, with siblings, with friends, with parents or other adults. It is plausible that who children spend their time with influences the duration, intensity and types of physical activity they engage in (Mackett et al., 2007). As described in the review presented in Chapter Three, one important contextual attribute which could modify physical activity is the companionship of other children. However, at present little is known about who children spend their time with after school, or how this is associated with their level of MVPA.

It is well established that the time children spend outdoors is more actively spent than time spent indoors (Cleland et al., 2008; Cooper et al., 2010). However it is unclear whether this time is spent alone, supervised by adults, or with other children. Time spent unsupervised by adults is thought to contribute significantly to children's daily physical activity (Veitch et al., 2006), while freedom from adult rules and structure is an important feature of active free play (Brockman et al., 2011b). In addition, child directed play has the potential to provide unique emotional, social and cognitive benefits (Burdette & Whitaker, 2005a). It is suggested that children's, and in particular girls' independent physical activity is increasingly limited due to parental concerns about safety (Carver et al., 2010; Carver et al., 2012; Hillman, 2006; Valentine & McKendrick, 1997). Since independent mobility is consistently associated with children's physical activity (Page, Cooper, Griew, Davis, & Hillsdon, 2009; Prezza et al., 2001; Wen et al., 2009), it is important to quantify how much unsupervised outdoor time children are afforded. Time spent with friends and siblings and the availability of other children to play are related to children's participation in unstructured outdoor physical activity (Jago et al., 2009; Thomson & Philo, 2004; Veitch et al., 2006; Veitch et al., 2010). These relationships may be of particular importance for children at the transition from primary to secondary school, as it is at approximately this age that independence from adults starts to develop (Jago et al., 2009; O'Brien et al., 2000).

To date, mostly qualitative and self or proxy report data have been used to characterise children’s indoor and outdoor leisure-time physical activity. Objective information from GPS receivers and accelerometers can more accurately quantify the intensity of physical activity occurring indoors and outdoors. Combining this with diary data reporting who children spend their time with provides a unique data set to describe a potentially important context for how physical activity may be modified. Consequently, the aim of this chapter is to use combined diary, GPS and accelerometer data to investigate who children spend their indoor and outdoor time with, and how this relates to MVPA after school.

## 5.3 Methods

This study used baseline data from the PEACH (Personal and Environmental Associations with Children's Health) project. Between September 2006 and July 2008, research staff at the University of Bristol recruited 1,307 year six (age 10-11 years) children from 23 state primary schools in Bristol, UK. The PEACH project investigates environmental and personal determinants of physical activity, eating behaviours and obesity in young people as they transition between primary and secondary school. The methods of the PEACH project have been described fully elsewhere (Page et al., 2009), and as such the following sections report details of the project relevant to the additional analyses carried out in this chapter. Written informed consent was obtained from a parent/guardian of all children who took part in the study. Ethical approval for the project was provided by University of Bristol Ethics Committee.

### 5.3.1 Physical activity.

Physical activity intensity was summarised at ten second epochs using an accelerometer (GT1M; ActiGraph LLC, FL, USA). Participants were asked to wear the accelerometer on a waist belt for seven continuous days. The method of Troiano, Berrigan, Dodd et al. (2008) was used to identify accelerometer non-wear time: periods of 60 minutes (or more) of zero values were discarded allowing for up to two minutes of non-zeroes per hour. This criterion was used in preference to shorter non-wear definitions (e.g. 10 or 20 minutes) which can result in unnecessary removal of data and underestimation of sedentary time in some subgroups, for example those who are overweight (Toftager et al., 2013). For inclusion in analyses participants were required to have recorded at least three hours of after school accelerometer data on at least one weekday.

### 5.3.2 Indoor/outdoor location.

Positional data were recorded every ten seconds using a GPS receiver (GPS; Foretrex 201, Garmin, Schaffhausen, Switzerland) (Rodriguez, Brown, & Troped, 2005). Participants wore the GPS receiver between the end of school and bed time on four consecutive school days. Participants were trained to turn the GPS receiver on at the end of school and off at bedtime. Research staff charged the units on day three of use due to limited battery life. Days with no GPS data were removed from the dataset.

### 5.3.3 Diary data.

Participants were asked to complete a one day recall diary for three school days. This diary was based on previous work (McKenna, Foster, & Page, 2004; Page et al., 2000). The children were asked to record the start and end time of after school activities starting with the first thing they did after leaving school. In addition to the start and end time, participants were asked to select who they were with for each activity from five options: on my own, with friend, with brother/sister, with mum or dad, with another grown up. To maximise the quality of the diary provided by the children, an annotated example was provided and explained verbally by the researcher to small groups of participants (<10). Participants were incentivised to complete diaries via vouchers provided for completion of all measures and personal prompts were provided by researchers and teachers to remember to complete diaries. Periods with no diary record were quantified and children who did not provide diary data on at least one day were excluded from analyses.

### 5.3.4 Other variables.

Height (m) and weight (kg) were measured using a stadiometer (SECA) and digital scales (indoor clothing, shoes removed). Participant BMI was calculated (body mass in kg divided by height in metres squared), and BMI standard deviation score

(BMISDS) was derived from standard tables (Cole, Bellizzi, Flegal, & Dietz, 2000). Age, sex and post-code were confirmed by the Local Education Authority. Minutes of daylight from 15:00 until sunset for the day of measurement were determined using standard tables (www.timanddate.com, accessed August 2013). The UK IMD 2007 score was defined using full home postcode.

### 5.3.5 Data processing.

Ten second epoch accelerometer and GPS data were matched using date and time stamps for the period between 15:00 and 22:00 on weekdays using STATA (version 12.0, College Station, TX) as previously described (Cooper et al., 2010). Each ten second epoch was also matched to computerised diary data using date and time stamps. The above data matching was processed by the University of Bristol. All further data processing was conducted by the author. Ten second epochs with accelerometer activity counts exceeding 383 (2296 counts per minute/6) were coded as MVPA (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008; Trost, Loprinzi, Moore, & Pfeiffer, 2011). The GPS receiver used in this study does not record positional data when inside a building. Consequently each epoch of accelerometer data with no corresponding GPS record was defined as indoors, while GPS matched accelerometer data were defined as outdoors. Any GPS point with a speed of greater than 15 kph was excluded as this was likely to represent an aberrant signal (e.g. reflection from a building) or motorised transportation (Maddison & Ni Mhurchu, 2009).

Epochs with GPS and accelerometry data but no matching diary data entries were removed from the analyses. Participants who did not provide combined accelerometer, GPS and diary data on at least one day were excluded from analyses. In addition, some children provided diary entries with overlapping times and these were also excluded (<1% of total). Total minutes spent and minutes of MVPA were summed according to who children were with and whether they were indoors or outdoors. For example all epochs classified as ‘indoors’ and ‘with mum or dad’ were summed to give the time spent indoors with mum/dad, and the MVPA recorded during that time. This resulted in ten (indoors/outdoors: on own, with friend, with brother/sister, with mum/dad, with other grown-up) distinct contexts of after school physical activity.

### 5.3.6 Data analyses.

Descriptive statistics (mean, standard deviation and percentage) of total time and time in MVPA were calculated by sex, social company and location (indoors/outdoors). Multivariate linear regression models were used to assess the contribution of time in each context to the total minutes of after school MVPA. This was expressed as the mean increase in minutes of MVPA for each hour spent in that context after adjusting for time spent in all the other contexts. In addition models were adjusted for potential a priori confounders (age, BMISDS, IMD, daylight hours). Due to well-established sex differences in daily physical activity, data for girls and boys were analysed separately (Reilly et al., 2008). Visual inspection of standardised residuals against predicted scores indicated some heteroskedacity and so robust (Huber-White) standard errors are reported. All analyses were conducted using Stata/SE (version 12.0, College Station, TX). Means (with standard deviations in parentheses) are reported where appropriate.

## 5.4 Results

The sample consisted of 230 girls and 197 boys with mean age 10.7 (0.5) years and BMI 18.3 (3.2) kg/m$^2$ who provided combined GPS, accelerometer and diary data on at least one measurement day.

### 5.4.1 Total after school MVPA and time indoors/outdoors

The figures below are derived from all valid accelerometer and GPS data recorded after school; this is the sum of epochs that were matched to a diary entry, plus those which had no corresponding time-matched diary entry recorded by the participant (i.e. missing diary data). Overall, girls recorded 21.7 (12.3) minutes of MVPA during the after school period while boys recorded 25.0 (13.4) minutes. The GPS data estimated that girls spent 21.0 (27.7) minutes outdoors after school while boys were outdoors for 20.3 (27.4) minutes during the same period. Matched accelerometer and GPS data suggested that girls recorded 4.3 (6.4) minutes or 19.8% of total after school MVPA outdoors, while for boys this value was 4.6 (7.1) minutes or 18.4%.

### 5.4.2 Time-matched of diary and accelerometer data

In contrast to those presented in section 5.4.1, the figures below refer only to the number of minutes of accelerometer data which were time-matched to participants' diary entries. They do not include remaining unmatched accelerometer data which had no corresponding diary record. Girls provided a mean of 155.5 (71.2) minutes of after school diary information, and this was time-matched to accelerometer data which included a mean of 13.4 (9.3) minutes of MVPA. Boys provided a mean of 160.9 (74.5) minutes of after school diary information, and this was time matched to accelerometer data which included on average 15.6 (11.1) minutes of MPVA.

Of all the valid after school accelerometer data, 40.5% of girls' and 38.3% of boys' accelerometer epochs could not be time matched to diary records because no diary entries had been recorded by the children during these periods. Consequently, 38.2% of girls' and 37.6% of boys' accelerometer recorded MVPA was not described by the participants in their diary. Table 5.1 reports the proportion of accelerometer epochs that were matched to GPS data (subsequently labelled outdoors), and the proportion of accelerometer epochs matched to a diary record, by hour.

Table 5.1 *Proportion of accelerometer epochs matched to GPS and diary records by hour.*

| Hour | Total accelerometer epochs | Matched to GPS record | | Matched to diary record | |
|---|---|---|---|---|---|
| | | Total | % | Total | % |
| 15:00-15:59 | 331189 | 35420 | 10.7 | 133588 | 40.3 |
| 16:00-16:59 | 322970 | 34014 | 10.5 | 247820 | 76.7 |
| 17:00-17:59 | 323090 | 23290 | 7.2 | 233386 | 72.2 |
| 18:00-18:59 | 316641 | 26200 | 8.3 | 207956 | 65.7 |
| 19:00-19:59 | 270367 | 14106 | 5.2 | 163343 | 60.4 |
| 20:00-20:59 | 193725 | 7272 | 3.8 | 96611 | 49.9 |
| 21:00-21:59 | 84595 | 1687 | 2.0 | 31200 | 36.9 |

*Abbreviation*: Global Positioning System (GPS).

### 5.4.3 Diary-matched time spent and MVPA according to context

Using the available combined accelerometer, diary and GPS data, Tables 5.2 (girls) and 5.3 (boys) summarise the time spent and MVPA recorded according to who children were with (from diary data) and whether they were indoors or outdoors after school (from GPS data). The figures refer only to the accelerometer and GPS data which were successfully time-matched to a diary record. As reported in section 5.4.2, approximately 40% of after-school accelerometer data (both MVPA and non-MVPA) had no corresponding diary record. This unmatched data is not included in totals for time spent or MVPA, and does not contribute to the denominator for calculation of percentages. Total after-school MVPA irrespective of diary record is reported in section 5.4.1.

Both girls (28.9%) and boys (28.3%) recorded more time with their mum/dad than other categories, followed by time spent alone (girls: 21.9%; boys: 24.7%). Girls spent least time with brother/sister (8.1%), while boys spent least time with other grown-ups (14.2%). Boys recorded the most MVPA when with their friends or mum/dad (both 25.0%), while girls recorded the most MVPA when with their mum/dad (23.9%).

The greatest share of time outdoors was spent with friends (girls: 32.4%; boys: 29.9%), followed by mum/dad (girls: 20.9%; boys: 28.4%). Both girls (2.9%) and boys (2.5%) spent a small percentage of the total after school period outdoors with friends. Amongst girls, the smallest proportion of time outdoors was spent with brother/sister (12.2%); while for boys least time outdoors was spent with other grown-ups (11.2%). Children's time indoors was mostly spent with mum/dad (girls: 29.8%; boys: 28.3%) or by themselves (girls: 22.1%; boys: 25.2%). Only 14.4% of girls' and of boys' indoor time was spent with friends.

Both girls (1.0 minutes, 32.3%) and boys (1.2 minutes, 38.7%) most commonly recorded outdoor MVPA in the presence of friends. Least outdoor MVPA was recorded with brother/sister (girls: 0.4 minutes, 12.9%; boys: 0.3 minutes, 9.7%) or other grown-ups for boys (0.3 minutes, 9.7%). Indoor MVPA was more evenly distributed, although for both girls (2.6 minutes, 25.0%) and boys (3.1 minutes, 24.8%) this was most commonly recorded with mum/dad.

Table 5.2 *Girls' matched after school time and MVPA by who they were with and indoor or outdoor location.*

| | On own | Friend | Brother/sister | Mum/dad | Other grown-up | Total |
|---|---|---|---|---|---|---|
| **Indoors** | | | | | | |
| Time spent (minutes) | 31.3 (32.9) | 20.4 (32.2) | 19.9 (30.4) | 42.1 (42.3) | 27.8 (42.8) | 141.5 (69.4) |
| Proportion of time indoors (%) | 22.1 | 14.4 | 14.1 | 29.8 | 19.6 | 100.0 |
| Proportion of all matched time (%) | 10.4 | 6.8 | 6.6 | 13.9 | 9.2 | 91.0 |
| Indoor MVPA (minutes) | 2.1 (3.0) | 2.0 (3.8) | 1.2 (2.0) | 2.6 (3.0) | 2.4 (4.5) | 10.4 (7.1) |
| Proportion of indoor MVPA (%) | 20.2 | 19.2 | 11.5 | 25.0 | 23.1 | 100.0 |
| Proportion of all matched MVPA (%) | 15.7 | 14.9 | 9.0 | 19.4 | 17.9 | 76.9 |
| **Outdoors** | | | | | | |
| Time spent (minutes) | 2.7 (8.5) | 4.5 (13.1) | 1.7 (7.7) | 2.9 (5.8) | 2.2 (6.0) | 13.9 (20.1) |
| Proportion of time outdoors (%) | 19.4 | 32.4 | 12.2 | 20.9 | 15.8 | 100.0 |
| Proportion of all matched time (%) | 1.7 | 2.9 | 1.1 | 1.9 | 1.4 | 9.0 |
| Outdoor MVPA (minutes) | 0.5 (1.4) | 1.0 (3.4) | 0.4 (2.1) | 0.6 (1.6) | 0.6 (1.9) | 3.1 (5.1) |
| Proportion of outdoor MVPA (%) | 16.1 | 32.3 | 12.9 | 19.4 | 19.4 | 100.0 |
| Proportion of all matched MVPA (%) | 3.7 | 7.5 | 3.0 | 4.5 | 4.5 | 23.1 |
| **Total** | | | | | | |
| Matched time spent (minutes) | 34.0 (35.5) | 24.9 (37.7) | 21.6 (32.9) | 45.0 (44.2) | 30.0 (44.7) | 155.5 (71.2) |
| Proportion of all matched time (%) | 21.9 | 16.0 | 8.1 | 28.9 | 19.3 | 100.0 |
| Total matched MVPA (minutes) | 2.6 (3.7) | 3.0 (6.0) | 1.6 (3.3) | 3.2 (3.8) | 3.0 (5.1) | 13.4 (9.3) |
| Proportion of matched MVPA (%) | 19.4 | 22.4 | 11.9 | 23.9 | 22.4 | 100.0 |

*Abbreviation*: Moderate to vigorous physical activity (MVPA).

*Note*: Values are presented as mean (SD) after school minutes or percentages as designated. ‘Matched’ refers to periods with available accelerometer, Global Positioning System and diary data.

Table 5.3 *Boys' matched after school time and MVPA by who they were with and indoor or outdoor location*

| | On own | Friend | Brother/sister | Mum/dad | Other grown-up | Total |
|---|---|---|---|---|---|---|
| **Indoors** | | | | | | |
| Time spent (minutes) | 37.2 (40.5) | 21.2 (32.8) | 26.1 (34.9) | 41.8 (44.1) | 21.3 (37.2) | 147.5 (73.3) |
| Proportion of time indoors (%) | 25.2 | 14.4 | 17.7 | 28.3 | 14.4 | 100.0 |
| Proportion of all matched time (%) | 23.1 | 13.2 | 16.2 | 25.9 | 13.2 | 91.5 |
| Indoor MVPA (minutes) | 2.3 (3.0) | 2.7 (6.2) | 1.9 (3.2) | 3.1 (4.0) | 2.5 (4.7) | 12.5 (9.3) |
| Proportion of indoor MVPA (%) | 18.4 | 21.6 | 15.2 | 24.8 | 20.0 | 100.0 |
| Proportion of all matched MVPA (%) | 14.7 | 17.3 | 12.2 | 19.9 | 16.0 | 80.1 |
| **Outdoors** | | | | | | |
| Time spent (minutes) | 2.5 (6.3) | 4.0 (12.3) | 1.8 (6.0) | 3.8 (6.8) | 1.5 (6.0) | 13.4 (20.6) |
| Proportion of time outdoors (%) | 18.7 | 29.9 | 13.4 | 28.4 | 11.2 | 100.0 |
| Proportion of all matched time (%) | 1.6 | 2.5 | 1.1 | 2.4 | 0.9 | 8.5 |
| Outdoor MVPA (minutes) | 0.5 (1.4) | 1.2 (4.0) | 0.3 (1.2) | 0.8 (1.9) | 0.3 (1.6) | 3.1 (5.7) |
| Proportion of outdoor MVPA (%) | 16.1 | 38.7 | 9.7 | 25.8 | 9.7 | 100.0 |
| Proportion of all matched MVPA (%) | 3.2 | 7.7 | 1.9 | 5.1 | 1.9 | 19.9 |
| **Total** | | | | | | |
| Matched time spent (minutes) | 39.7 (41.8) | 25.2 (38.7) | 27.9 (37.2) | 45.6 (46.6) | 22.8 (38.4) | 160.9 (74.5) |
| Proportion of all matched time (%) | 24.7 | 15.7 | 17.3 | 28.3 | 14.2 | 100.0 |
| Total matched MVPA (minutes) | 2.8 (3.4) | 3.9 (8.1) | 2.2 (3.7) | 3.9 (4.8) | 2.8 (5.1) | 15.6 (11.1) |
| Proportion of matched MVPA (%) | 17.9 | 25.0 | 14.1 | 25.0 | 17.9 | 100.0 |

*Abbreviation*: Moderate to vigorous physical activity (MVPA).

*Note*: Values are presented as mean (SD) after school minutes or percentages as designated. 'Matched' refers to periods with available accelerometer, Global Positioning System and diary data.

### 5.4.4 Associations between time in specific contexts and after school MVPA.

Table 5.4 (girls) and Table 5.5 (boys) contain data from multivariate linear regression models examining relationships between hours spent in specific contexts and minutes of after school MVPA. The models explained 34.4% of girls' and 30.1% of boys' variance in after school MVPA. For both girls and boys, outdoor contexts exhibited stronger associations with MPVA than indoor contexts. Time spent outdoors in the company of friends was particularly important for both boys and girls, with an increase of approximately 17 minutes of MVPA recorded for every additional hour spent in this context. Similarly, when girls spent time outdoors with siblings, they recorded on average 21.21 minutes of MVPA each hour. This relationship was similar for boys but non-significant. When indoors, time with friends was positively associated with MVPA, however relationships were weaker than when outdoors (4.61 and 7.42 minute increase in MVPA accrued per hour for girls and boys respectively). Relationships of similar direction and magnitude to these were also observed between time indoors with other grown-ups and MVPA for both girls and boys. Time spent alone either indoors or outdoors was not associated with MVPA regardless of sex.

Table 5.4 *Multivariate linear regression model of time in specific contexts and total after school MVPA amongst girls (n = 230).*

| | | *b*-value | 95% CI | | t | *p* |
|---|---|---|---|---|---|---|
| **Outdoors** | On own | 7.27 | −1.08 | 15.61 | 1.72 | 0.088 |
| | Friend | 17.35 | 4.47 | 30.24 | 2.65 | 0.009 |
| | Brother/sister | 21.21 | 14.17 | 28.25 | 5.94 | 0.000 |
| | Mum/dad | 5.55 | −6.34 | 17.45 | 0.92 | 0.359 |
| | Other grown-up | 12.76 | −1.96 | 27.50 | 1.71 | 0.089 |
| **Indoors** | On own | 1.78 | −0.58 | 4.14 | 1.49 | 0.138 |
| | Friend | 4.61 | 1.37 | 7.85 | 2.81 | 0.005 |
| | Brother/sister | 2.93 | 0.65 | 5.22 | 2.53 | 0.012 |
| | Mum/dad | 2.87 | 0.98 | 4.76 | 2.99 | 0.003 |
| | Other grown-up | 5.33 | 2.95 | 7.71 | 4.41 | 0.000 |
| | | | | | $R^2 = 0.344$; $p < 0.001$ | |

*Abbreviation*: Moderate to vigorous physical activity (MVPA).

*Note*: Adjusted for standardised body mass index, age, index of multiple deprivation, daylight. *b*-value: mean increase in minutes of MVPA for each hour spent in that context.

Table 5.5 *Multivariate linear regression model of time in specific contexts and total after school MVPA amongst boys (n = 197).*

| | | *b*-value | 95% CI | | t | *p* |
|---|---|---|---|---|---|---|
| **Outdoors** | On own | −0.41 | −13.27 | 12.45 | −0.06 | 0.949 |
| | Friend | 17.53 | 2.76 | 32.31 | 2.34 | 0.020 |
| | Brother/sister | 16.95 | −12.12 | 46.01 | 1.15 | 0.251 |
| | Mum/dad | 9.00 | −6.25 | 24.25 | 1.16 | 0.246 |
| | Other grown-up | 8.54 | −10.79 | 27.87 | 0.87 | 0.385 |
| **Indoors** | On own | −0.64 | −2.92 | 1.63 | −0.56 | 0.579 |
| | Friend | 7.42 | 2.99 | 11.85 | 3.30 | 0.001 |
| | Brother/sister | 2.80 | −0.14 | 5.74 | 1.88 | 0.062 |
| | Mum/dad | 1.77 | −0.39 | 3.93 | 1.62 | 0.108 |
| | Other grown-up | 4.44 | 1.98 | 6.90 | 3.56 | 0.000 |
| | | | | | $R^2 = 0.301$; | $p < 0.001$ |

*Abbreviation*: Moderate to vigorous physical activity (MVPA).

*Note*: Adjusted for standardised body mass index, age, index of multiple deprivation, daylight. *b*-value: mean increase in minutes of MVPA for each hour spent in that context.

## 5.5 Discussion

The main findings of this study is that children's participation in MVPA is associated with who and where the after school period in spent, and that in particular, time spent outdoors with other children is a key context for participation in MVPA. Previous studies have investigated children's independent mobility and independent physical activity, demonstrating that greater license to leave the home unaccompanied is positively associated with time outdoors (Wen et al., 2009) and physical activity (Page et al., 2009). This work builds upon those findings by quantifying the time children spend alone, with adults, or with other children, and matching this with objective measures of physical activity and indoor/outdoor location. Participants reported spending most time alone or with their parents, especially during indoor time which was very rarely spent with other children. Although children spent few minutes outdoors after school, when they were outdoors they were most likely to be with friends. The accumulation of long periods spent indoors alone or supervised by adults and comparatively little time spent outdoors with other children supports the view that there are limited opportunities for primary school children to go outdoors without an adult (Jago et al., 2009; Valentine & McKendrick, 1997). This is concerning given that independent mobility has an established association with children's physical activity (Page et al., 2009; Prezza et al., 2001; Wen et al., 2009), and that time outdoors is approximately three times more likely to spent engaging in MVPA (Cooper et al., 2010).

It has been reported in other UK-based studies that approximately one third of children are only allowed outdoors without an adult when in the company of other children (Mackett et al., 2007). Previous work also suggests that neighbourhood relations and friends are linked to perceptions of safety for both parents and children (Mikkelsen & Christensen, 2009; Valentine, 1997). Neighbourhood relations and having someone to play with may also positively influence parental decisions about independent mobility (Prezza et al., 2001). However, from the present cross-sectional data it is not possible to distinguish whether time outdoors facilitates being with friends, or whether the companionship of other children is a pre-requisite of parents' willingness to grant independent mobility. Parents may be vulnerable to a cycle of increased safety concerns linked to limited independent mobility and the subsequent social norm of children not being allowed out to play in the local environment (Carver et al., 2008; Ergler et al., 2013). Valentine & McKendrick (1997) suggest that a move from unstructured play to structured forms of physical activity has prompted suspicion of those children in public space without adults. Similarly, Ergler, Kearns & Witten (2013) report that the normalisation of indoor play is especially pronounced in urban areas because children are unable to use informal areas such as sidewalks. The regression analyses indicate that alongside outdoor time with friends, indoor time with friends was also positively associated with MVPA. Time spent with other children therefore appears crucial for physical activity, and this may be augmented by being outdoors. Recently published longitudinal data report that an increase in the number of friends between primary and secondary school is associated with an increase in girls' MVPA (Jago, Page, & Cooper, 2012). Further longitudinal work is necessary to understand whether the formation of friendship groups is a product of, or fundamental determinant for independent mobility and outdoor physical activity. Based on such work it may be possible to promote physical activity by developing neighbourhood community links amongst children and parents, and seeking to restore the social norm of children using the outdoors as a setting for physical activity.

Parents are reported to be more protective of girls due to greater perceived risk and to subsequently limit their independence (Carver et al., 2010; Carver et al., 2012; Hillman et al., 1990). This research supports this indicating that indoor contexts are more important for girls' physical activity than for boys'. Time spent indoors with friends was important for both sexes, however periods indoors with siblings or parents were only associated with MVPA amongst girls. These findings echo qualitative work by Brockman et al. (2011a) which reported that girls were more likely to report active play centred on the home and with family members. Previous research has reported that similar numbers of boys and girls are allowed outdoors without an adult, but that for girls this was more likely to be conditional on other children being present (Mackett et al., 2007). The strength of association between time spent outdoors with friends or siblings and MVPA in this study supports the hypothesis that girls who do have other children to accompany them outdoors are likely to be more active. Thus while safety in numbers and fostering friendship groups may be important to facilitate after school MVPA (Jago et al., 2012), it is encouraging that despite their limited independence girls appear to find ways to be active indoors. These findings tie with those of Atkin et al. (2008) who found that technology based sedentary behaviour during the 'critical hours' was higher amongst boys than girls. Future research and interventions may benefit from not only increasing the time children spend outdoors with others, but also seeking to maximise the potential of indoor environments for physical activity and limiting the time children spend alone.

It is not clear why time outdoors with friends is a particularly valuable source of MVPA. It may be due to the freedom from adult rules and structure (Brockman et al., 2011b; Veitch et al., 2007). Alternatively, it is possible that children's movement patterns and behaviours vary depending on whether they are with adults or other children. It has been reported that children's movement is more meandering when away from adults (Mackett et al., 2007), and some children like to do activities (such as non-permitted behaviours) outside the view of adults (Soori & Bhopal, 2002). This paper emphasises the importance of time spent with other children, however it should also be highlighted that many children rely on adults to supervise their activity. Strategies and policy that enable adults to supervise physical activity and encourage families to be active together may be beneficial for individuals across the lifespan. This study also suggests that time spent indoors with adults other than mum/dad is positively associated with MVPA for both boys and girls, and this may be indicative of after school supervision. It is necessary to understand more about what behaviours indoors contribute to MVPA and how these may be manipulated to increase opportunities for physical activity. For example, after school clubs offer a safe indoor environment for physical activity but opportunity for this may be limited due to the inclusion of academic and snack times (Trost et al., 2008).

Findings regarding the degree of variation in MVPA explained by time spent in these different outdoor contexts should be treated with caution. The MVPA recorded in each specific context was minimal, often equating to only one or two minutes. Whilst the relationship between context-specific time spent and MVPA was tested for linearity during regression diagnostics, it is plausible that the *b*-values reported above are not scalable to periods of an hour or more as implied. If this is the case, then larger increases in time spent in contexts with strong associations with MVPA may not necessarily be associated with similarly large increases in MVPA. Despite this, the results are indicative of a trend for time spent with other children outdoors being more strongly associated than with adults or alone, particularly when indoors. Research regarding bout frequency and duration in these contexts would benefit understanding in this area.

### 5.5.1 Strengths and limitations.

A key strength of this study is the combination of accelerometer, GPS and diary data to describe the context of children's physical activity. This allowed exploration of not only who children spend their time with, but whether this related to objectively measured location (indoors vs. outdoors) and physical activity. Whilst the sample size was large and was drawn from a number of different primary schools representing a large English city, the results may not be generalisable to other locations or age groups. Furthermore, given that only children who provided matched accelerometer, GPS and diary data were included, the sample may not be wholly representative of the wider population. Some included participants provided only one day of combined data which may limit the reliability of the findings (this limitation is discussed further in section 8.4).

Consistent with previous studies that have combined diary and objective data, there are likely to have been errors in the children's report of their activities and consequent MVPA classification (Goodman, Mackett, & Paskins, 2011). For example, children may have recorded time spent with friends when in fact they were also under the supervision of an adult. A clear limitation of the study is that a significant proportion of time between 15:00 and 22.00 was unaccounted for due to missing diary entries reporting who the children were with. Diary records were not available for 40.5% of girls and 38.3% of boys after school time, and the proportion of missing diary data increased by hour up until bedtime. The participants were asked to record what they did after school, and as such periods where their behaviour was unstructured or intermittent may be more difficult to report (Kohl et al., 2000). This may especially be the case for children who lack the cognitive and linguistic ability to describe their behaviour (Trost et al., 2000a). Unstructured activity may be more likely to reflect low intensity physical activity so a greater proportion of this might be missing data. This is supported by the fact that missing diary data contributed disproportionally fewer minutes of MVPA. However, approximately one third of MVPA (girls: 8.3 minutes; boys: 9.4 minutes) was not recalled and described by children in their diary. Examining the source of this unreported physical activity should be the subject of further research.

Girls and boys recorded 21.7 and 25.0 minutes of total after school MVPA respectively. These figures include accelerometer data matched to diary records (girls: 13.4 minutes; boys: 15.6 minutes) and that for which there was no corresponding diary record (girls: 8.3 minutes; boys: 9.4 minutes). Children are reported to record the majority of their MVPA outside of school hours on week-days (Gidlow et al., 2008). Consequently this total is low in view of current physical activity guidelines of 60 minutes per day (Department of Health, 2011), but perhaps not unsurprising given the number of children who fail to meet these recommendations (Ekelund et al., 2011). Accelerometers are unable to accurately record physical activity during load carrying, using stairs or during swimming and cycling activities (Sirard & Pate, 2001; Welk et al., 2000), and the figures above may therefore represent an underestimation of after school MVPA due to these limitations. Furthermore, use of MVPA cut points is controversial because of the variety of calibration studies that have been conducted. It is possible to show that the same group of children wearing the same accelerometer are either sufficiently, or insufficiently active depending on the cut point used (Corder et al., 2008; Reilly et al., 2008). Although the cut point used in this study was based upon the best available evidence of validity (Trost et al., 2011), use of an alternative threshold could have yielded different findings. It could also be argued that use of cut points to dichotomise data in this way discards valuable continuous information. Use of mean counts may be alternative to investigate how physical activity varies between different contexts, but has the disadvantage of not revealing the context-specific contributions towards total MVPA.

It is likely that there were errors in the differentiation of physical activity location by the GPS receiver. The assumption that absence of a GPS signal represented indoor time was originally used by Cooper et al. (2010). However, this method underestimates time outdoors due to slow signal acquisition time when individuals move indoor to outdoor locations. Furthermore, although children were trained to turn the GPS on when leaving school it is possible that some delay may have occurred leading to further misclassification of outdoor data. The degree of misclassification is not known. This could have been examined using GIS to compare predicted indoor time with GPS data mapped to outdoor locations. Alternatively, periods where children were predicted to be indoors could be compared with peaks of accelerometer counts during periods of activity known to occur outdoors, for example the school commute. In particular, both of these additional analyses would reveal the degree to which signal acquisition times contributed towards misclassification of outdoor time as indoors.

The present study was cross-sectional, only recorded after school week-day activities during term-time and did not adjust for clustering within schools. The regression models were adjusted for four potentially confounding variables. These were chosen *a priori* on the basis of past research that has demonstrated their relationship with children's independent physical activity (Page et al., 2009). Variables were entered into the regression model using forced entry because it was deemed that there was sufficient theoretical rationale. However, bivariate associations of these variables with independent and dependent variables were not examined. The possibility therefore remains that one or more of these 'confounders' lies on a casual pathway between the context-specific time variables and MVPA, mediating rather than confounding their relationship(s). This over adjustment can obscure a true effect or create an observed effect when none exists (Schisterman, Cole, & Platt, 2009). It should therefore be noted that alternative specifications of the models may have resulted in different parameter estimates.

Longitudinal work is required to fully understand the impact of the variables explored here, particularly the impact of the companionship of other children on independent mobility and unstructured outdoor physical activity. Whilst at present it is clear that children's outdoor time with friends represents a very small proportion of leisure time, this represents an important intervention target. This is because of the potential for change during the after school period, the greater accumulation of MVPA during time spent in this context, the additional social benefits of this type of activity (Burdette & Whitaker, 2005a), and the harmful effects of sedentary behaviours occurring indoors (Atkin et al., 2008).

### 5.5.2 Conclusions.

This study indicates that children spend most of the after school period indoors alone or with parents and very little time outdoors playing with other children. However, that time which is spent outdoors with friends makes the greatest contribution towards outdoor MVPA. Time outdoors with other children was most strongly associated with MVPA whereas time spent alone was not associated with MVPA either indoors or outdoors. In addition to promoting active time indoors, strategies to foster neighbourhood friendship groups and remove barriers which restrict time outdoors should be investigated further and considered as components of multi-level interventions to promote physical activity.

## 5.6 What Did This Chapter Contribute?

- Using data from the PEACH project collected between 2006 and 2008, it was shown that during the after school period 427 children aged 10–11 children were most often with their mum/dad or alone, especially when indoors.
- When outdoors, more time was spent with friends than other people or alone.
- Regression analyses suggested hours outdoors with friends were positively associated with minutes of MVPA for both girls and boys.
- Time spent alone was not associated with MVPA regardless of sex or indoor/outdoor location.
- Combining data from different measurement tools is an informative approach which develops understanding of the context of children's physical activity.
- Interventions to increase physical activity may benefit from fostering friendship groups, and limiting the time children spend alone after school.
- The study recorded only after school physical activity and did not investigate whether or not activity occurred in structured or unstructured contexts.

# Chapter Six

# Indoors or Outdoors? Examining the Use of GPS Data to Differentiate Physical Activity Location


## 6.1 Abstract

Global Positioning Systems provide valuable insight about the context of physical activity. It is of particular interest to use GPS data to determine whether accelerometer data are recorded indoors or outdoors. Sum signal to noise ratio (SNR) and ratio of satellites in view to those connected (RCA) fluctuate with environmental changes. This chapter aimed to assess the feasibility of using GPS data to differentiate indoor and outdoor location, and establish the optimal threshold for this purpose

From September 2011 and February 2012, a free living convenience sample of 8 adults in Edinburgh wore a Qstarz BT-Q1000eX GPS receiver recording position at 0.2Hz for approximately five hours. Location was coded indoors or outdoors by an observer. Indoor or outdoor location was predicted using SNR and RCA data. Receiver operator characteristic (ROC) curves were plotted to compare the discriminating ability of both test ratios. Youden's J statistic determined the optimal threshold.

Eight participants recorded 31125 (24.1% outside) epochs of GPS data. Area under the ROC curves indicated that both test ratios had statistically significant discriminating ability, however area under the ROC curve was greater for the SNR than the RCA (0.982 vs. 0.851; $p < 0.0001$). Peak Youden's J statistic for the SNR was 0.930 compared to 0.552 for the RCA. The threshold with the highest Youden's J statistic was SNR of 212.

The 212 SNR threshold is suggested for determining indoor or outdoor location using this GPS receiver. This threshold represents compromise between successfully predicting both indoor and outdoor time. Future work should examine these methods in different populations and settings.

## 6.2 Introduction

As described in Chapter Four, this research uses a combination of accelerometer, diary and GPS methods to understand the context of physical activity occurring indoors and outdoors. The GPS consists of 32 satellites orbiting the Earth, with the GPS receiver determining position by timing the signals sent by these satellites. When outdoors, the GPS receiver detects more satellites and receives a stronger signal from each (Kerr, Duncan, & Schipperjin, 2011), as shown in Figure 6.1.

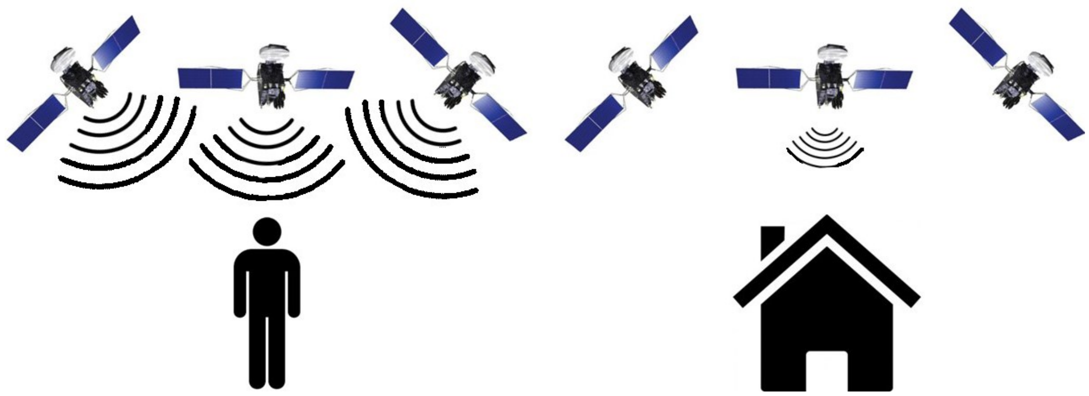


Figure 6.1 *Example of the number and strength of signals from Global Positioning System outdoors (left) and indoors (right).*

The previous chapter used the presence or absence of GPS signal to distinguish between outdoor and indoor time respectively. This assumption, originally used by Cooper et al. (2010), underestimates time outdoors due to slow signal acquisition time when individuals move indoor to outdoor locations. Outdoor time may have also been incorrectly classified as indoor time because although children were trained to turn on the GPS receiver at the end of school, this may not have been the case. Battery and memory capacity limitations of the GPS receiver itself meant it was necessary for fieldworkers to exchange units during the observation period. For the work that follows in Chapter Seven, it is necessary to develop a method that limits misclassification of indoor and outdoor time, does not require children to turn equipment on and off, and which can capture data from an entire observation period without the requirement to exchange devices. The Qstarz range of devices (Qstarz International, Taiwan, Republic of China) offer such capabilities due to extended battery life, memory capacity, and maintenance of signal acquisition even in indoor locations. By considering the ratio of satellites connected to the receiver to those available overhead (RCA), or the total signal strength (SNR), it may be possible to use a threshold value to differentiate whether the GPS receiver is indoors or outdoors (Kerr et al., 2011). This chapter aims to: 1) compare the ability of these two methods to differentiate indoor/outdoor location; and 2) identify the optimal threshold for differentiating indoor/outdoor location.

## 6.3 Methods

### 6.3.1 Data collection.

Ethical approval for the study was granted by The Moray House School of Education Ethics Committee at The University of Edinburgh. Between September 2011 and February 2012, seven males and one female wore two devices on an elasticated waist band: a GPS receiver (Qstarz BT-Q1000eX; Qstarz International, Taiwan, Republic of China) and an accelerometer (GT3X+; Actigraph LLC, FL, USA). Both devices were set to record at a 5 second (0.2 Hz) epoch. It is common for GPS data to be interrupted due to signal loss, but to fully assess the capacity of the GPS data to determine location it was essential to include these lost periods in the analysis. The accelerometer was therefore used to provide a continuous time sample for GPS matching by time and date, allowing analysis of periods when the GPS receiver was not receiving a signal. Data from the GPS receiver are time stamped using Coordinated Universal Time (UTC). Accelerometer data take their time stamp from the clock on the computer on which they are initialised. Since computer clocks can be inaccurate, the computer clock was matched to UTC immediately before initialisation.

Participants wore the GPS receiver and accelerometer for a period of approximately five hours. During this time they continued their normal daily activities. A single observer in close proximity recorded the start time, end time, and times of transition between indoor and outdoor locations. Indoor time was classified as periods spent inside buildings. All other periods, including time spent under bridges, in tunnels, under canopies, and in motorised transport, were classified as outdoors. A transition was defined as the second when the participant passed through a door/opening. All times were recorded to one second accuracy using a digital watch also matched to UTC. All data collection took place in Edinburgh, UK, and the time of data collection varied by participant.

### 6.3.2 Data processing.

Data from the GPS receiver were downloaded using QTravel software (v1.41; Qstarz International, Taiwan, Republic of China). Accelerometer data were downloaded using ActiLife software (v5.9.2; Actigraph LLC, FL, USA). Accelerometer and GPS data were then matched using time stamps and programming script. The GPS output includes a report of the number of satellites available overhead and the number of satellites connected to the receiver. From these, the ratio of satellites connected to satellites available (RCA) was calculated. This value ranged from 0 to 1. Also included in the output was the sum of the signal-to-noise ratio for all connected satellites. This value ranged from 0 to 450.

The RCA and SNR values are at their peak when outdoors in open environments, and degrade when under canopies, near high sided buildings, heavy tree cover, inside buildings or in the presence of other obstructions. The RCA and SNR data were available for every five second epoch of the observation periods, except at times of signal drop out. For each epoch with no GPS data, the RCA and SNR were set to zero values. Whilst it is common for GPS data with spuriously high speeds, elevations and locations to be excluded from analyses, in this study all GPS data were utilised as RCA and SNR data could still be used to estimate indoor/outdoor location.

Each five second epoch was coded as either indoors or outdoors using times from independent observation. All epochs were coded regardless of whether GPS data were present. In cases where a transition occurred between epochs, the time was rounded up on each occasion (e.g. if a transition from indoors to outdoors occurred at 12:00:01, and records were available at 12:00:00 and 12:00:05, then epochs would be coded indoors up to and including 12:00:05).

### 6.3.3 Statistical analysis.

Receiver operating characteristic (ROC) curves for both tests were plotted using SPSS (v17.0, SPSS Inc., IL, USA) to establish the accuracy of each for differentiating indoor/outdoor location on an epoch by epoch basis. The ROC curve plots specificity vs. sensitivity for all possible thresholds. In this study, sensitivity refers to the ability of the test to correctly identify outdoor epochs (true positives), while specificity refers to the ability of the test to correctly identify indoor epochs (true negatives). The area under the curve (AUC) quantifies the overall discriminating ability of a test. An area of 0.5 is representative of a test with no discriminating ability. The closer the ROC curve to the left and upper limits of the graph, the better the diagnostic ability of the test (a perfect test has an area under the ROC curve of 1.0). This method of analysis was used because for the purpose of this thesis research, each individual GPS record is used to classify a single time matched accelerometer record. Individual ROC curves were constructed in the first instance and checked to assess suitability for pooling. One potential outlier was identified due to inconsistency with the other ROC curves; however, since removing this participant had no effect on analyses, the data were included.

Data were subsequently pooled and used to construct pooled ROC curves. The overall discriminating ability of the RCA and SNR tests was compared using MedCalc (v12, MedCalc Software bbva, Mariakerke, Belgium). The method of Hanley and McNeil (1982) for comparing the area under paired ROC curves was adopted. Area under ROC curve values of > .90 were considered excellent, .80-.89 good, .70-0.79 fair and < .70 poor (Metz, 1978). The overall accuracy of individual thresholds was derived by dividing the total number of correctly classified epochs by the total number of epochs recorded. However, because overall accuracy does not provide equal weighting to false positive and false negative values, thresholds for classifying indoor or outdoor location were also examined using Youden's J statistic (sensitivity + specificity -1). Means (with standard deviations in parentheses) are reported where appropriate.

## 6.4 Results

One female and seven male adult participants wore the GPS receiver and were observed for a mean duration 5.4 (1.7) hours. This provided 31125 five-second epochs for entry into the pooled ROC analysis, of which 22% were observed to be outdoors. Further details regarding the actual minutes spent indoors and outdoors by each participant are reported in Table 6.1. A range of indoor and outdoor locations were visited during the eight observation periods, including: inner city, suburban, rural, open greenspace, office buildings, shopping centres, gymnasiums, outdoor sports facilities, houses and flats.

Of the 31125 epochs used to generate ROC curves, 5814 were missing GPS records due to signal loss. These epochs were coded ‘0’ as inside for analyses. As shown in Table 6.2, almost all (5751 out of 5814) of these epochs with missing GPS data occurred while participants were indoors; 63 records were incorrectly classified indoors when in fact the signal loss occurred outdoors.

Table 6.1 *Observed time spent indoors and outdoors for eight participants.*

| | Indoors | | Outdoors | |
|---|---|---|---|---|
| Participant | Minutes | % | Minutes | % |
| 1 | 185.9 | 58.5 | 131.9 | 41.5 |
| 2 | 413.5 | 84.7 | 74.6 | 15.3 |
| 3 | 248.4 | 79.6 | 63.6 | 20.4 |
| 4 | 281.7 | 84.6 | 51.3 | 15.4 |
| 5 | 244.5 | 74.9 | 82.0 | 25.1 |
| 6 | 256.8 | 80.3 | 63.0 | 19.7 |
| 7 | 71.9 | 57.4 | 53.3 | 42.6 |
| 8 | 320.7 | 86.3 | 50.7 | 13.7 |
| Mean | 252.9 (99.0) | 78.0 | 71.3 (26.9) | 22.0 |

*Note*: values presented as Mean (SD) where appropriate.

Table 6.2 *Missing GPS data as percentage of total epochs recorded indoors and outdoors.*

| | Indoors | | | Outdoors | | |
|---|---|---|---|---|---|---|
| Participant | Total | Missing GPS | % | Total | Missing GPS | % |
| 1 | 2231 | 574 | 25.7 | 1583 | 20 | 1.3 |
| 2 | 4962 | 431 | 8.7 | 895 | 22 | 2.5 |
| 3 | 2981 | 84 | 2.8 | 763 | 0 | 0.0 |
| 4 | 3380 | 437 | 12.9 | 615 | 0 | 0.0 |
| 5 | 2934 | 2390 | 81.5 | 984 | 16 | 1.6 |
| 6 | 3082 | 1601 | 51.9 | 756 | 0 | 0.0 |
| 7 | 863 | 0 | 0.0 | 640 | 5 | 0.8 |
| 8 | 3848 | 234 | 6.1 | 608 | 0 | 0.0 |
| Total | 24281 | 5751 | 23.7 | 6844 | 63 | 0.9 |

*Abbreviation*: Global Positioning System (GPS).

### 6.4.1 Comparison of discriminating ability of both tests.

Figure 6.2 depicts ROC curves for both test ratios using pooled data from all eight participants. The curves show the trade-off between sensitivity and specificity for the full range of respective thresholds. For both tests, using a higher threshold results in an increase in the detection of true indoor epochs (greater specificity), but is also associated with a decrease in the detection of true outdoor epochs (poorer sensitivity). The SNR maintains very high sensitivity scores alongside high specificity scores as the threshold becomes higher. In comparison, when specificity is increased by using a higher RCA, sensitivity diminishes more rapidly.

The SNR had area under the ROC curve of 0.982 (95% CI: 0.981, 0.984), and was statistically significantly different from 0.500 ($p < 0.001$), the area under the ROC curve for a test with no discriminating ability. The RCA had an area under the ROC curve of 0.851 (95% CI: 0.847, 0.855), and was also statistically significantly different from 0.500 ($p < 0.001$). The difference between the area under the ROC curve for the two test ratios was 0.131, (95% CI: 0.127, 0.135), indicating the SNR has statistically significantly greater discriminating ability than the RCA ($p < 0.001$).

### 6.4.2 Optimal threshold for differentiating indoors/outdoors.

Table 6.3 reports the RCA and SNR thresholds with the highest Youden's J statistic. Also reported are how these scores translate to overall percentage of correctly classified epochs (accuracy), and subsequent predictions of total time spent inside and outside. The 212 SNR threshold yielded the highest Youden's J statistic and was more accurate than optimal threshold for the RCA. The SNR threshold of 212 correctly identified 96% of outdoor epochs (sensitivity) and 97% of indoor epochs (specificity), meaning that overall, 96.8% of all 31125 epochs were correctly classified (accuracy). In contrast the most accurate RCA threshold correctly identified 72.4% of epochs (see Table 6.3).

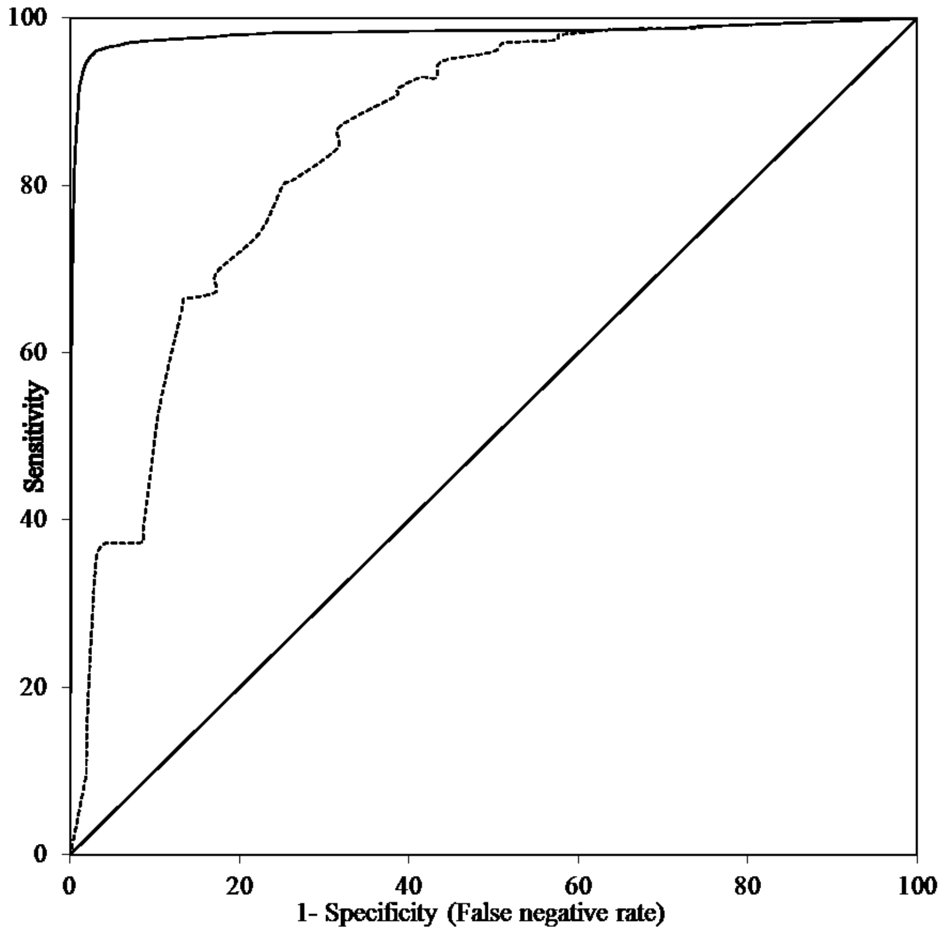



Figure 6.2 *Receiver operating characteristic curves of signal-to-noise ratio (solid curve) and ratio of satellites connected to satellites available (broken curve).* *Note*: Solid diagonal line represents area under the curve of zero, i.e. no discriminating ability.

Table 6.3 *Comparison of predicted indoor and outdoor time with observed values.*

| | Observed | Predicted by 212 SNR | Predicted by 0.667 RCA |
|---|---|---|---|
| Sensitivity (true outdoors) | - | 0.960 | 0.870 |
| Specificity (true indoors) | - | 0.970 | 0.682 |
| Youden's J statistic | - | 0.930 | 0.552 |
| Accuracy | - | 96.8% | 72.4% |
| Indoor time (minutes) | 2023.4 | 1986.4 | 1454.0 |
| Outdoor time (minutes) | 570.3 | 607.3 | 1139.8 |

*Abbreviations*: Signal-to-noise ratio (SNR), ratio of satellites connected to satellites available (RCA).

### 6.5 Discussion

The RCA and SNR are two variables present within the GPS output, both of which have a higher value when outdoors compared to indoors. This chapter examined whether it is possible to use these variables in conjunction with a threshold to differentiate individual epochs as indoors or outdoors. In particular, the study aimed to compare the discriminating ability of the two methods using ROC curves, and also aimed to identify the optimal threshold for differentiating indoor and outdoor epochs.

The main outcome of this chapter is that compared to the RCA, the SNR has superior ability to differentiate indoor or outdoor location. This is evident when inspecting the respective ROC curves, comparing the area under the ROC curves statistically, and when comparing the overall number of epochs correctly classified (the accuracy). Using the criteria of Metz (1978), the SNR has ‘‘excellent’’ discriminating ability, while the RCA can be considered ‘‘good’’. Researchers wishing to distinguish the indoor and outdoor locations of participants wearing GPS receivers should therefore use the SNR in preference to the RCA.

In addition to comparing the two tests, this chapter also aimed to establish a threshold, above which all GPS data points would be classified as being outdoors. To inform this decision, Youden's J statistic, a composite score of the sensitivity and specificity of particular threshold was used. Since there is an inverse relationship between the sensitivity and specificity of any diagnostic test (with only two outcomes), it is rare to be able to choose a threshold at which both sensitivity and specificity are at their optimal value (Kirkwood & Sterne, 2003). This means that assessing only the overall accuracy of a threshold is insufficient, as scores are impacted by the weighting between false positive and false negative values. Youden's J statistic is useful because it represents a compromise, in this case between maximising the detection of true outdoor epochs (sensitivity) and true indoor epochs (specificity). The optimal threshold had a Youden's J statistic of 212 SNR, and this was associated with an accuracy of 96.8% of all 31125 epochs being correctly classified as indoors or outdoors. It has been demonstrated that SNR scores in the range 225 to 275 can be used to determine indoor or outdoor location with confidence in free living adults and pre-school children in childcare (Lam et al., 2013; Tandon, Saelens, Zhou, Kerr, & Christakis, 2013). The optimal threshold in the present study was at a lower SNR and fell outside of this 225 to 275 range, however sensitivity and specificity scores were higher and maintained greater overall accuracy across a broader range of thresholds. The present study provides further evidence that this method can be used to accurately predict indoor and outdoor location. Variation in the optimal threshold between studies may be a product of differences in geographic location, wear time compliance and data processing steps such as aggregation into minutes. Whilst Youden's J was high over a range of thresholds, with corresponding variation in sensitivity and specificity, it is not recommended that investigators tailor the choice of threshold to suit the needs of particular research questions (e.g. a focus on time indoors or time outdoors). Instead, the choice of threshold should always minimise misclassifications overall (i.e. the sum of incorrectly classified indoor and outdoor epochs).

Use of the SNR from the Qstarz GPS receiver and application of the optimal threshold of 212 is an accurate tool for determining the indoor or outdoor location of the wearer. The data presented in this chapter provide evidence that this method can be applied on an epoch by epoch basis, and consequently lends itself to the description of individual epochs of matched accelerometer data. This combination offers an automated, objective method for measuring outdoor physical activity. Time outdoors has previously been measured by self-report (Wen et al., 2009) and parental report (Cleland et al., 2008) in child populations. This combination of GPS and accelerometer data is preferable because it negates many of the problems of self-report exacerbated in children, most notably recall error (Corder et al., 2008). In addition, this method permits accurate analysis of the duration and intensity of physical activity occurring indoors and outdoors. Because GPS data recorded indoors may not provide an accurate estimate of longitude and latitude due to 'jitter'(Kerr et al., 2011), the accurate filtering of indoor epochs using this method may also be useful for investigators wishing to use GIS for analysis.

Cooper et al. (2010) have previously used a GPS receiver (Garmin Foretrex 201) to identify indoor and outdoor physical activity, and this method was also used to examine data from the PEACH Project in Chapter Five. The absence or presence of a GPS signals was used to differentiate indoor and outdoor location respectively. This assumption was acceptable given that this unit often failed to receive any signal when indoors. In contrast, the Qstarz GPS receiver used here continues to receive a signal when indoors, although some signal drop-out does occur. The data presented in Table 6.2 demonstrate that the method used by Cooper et al. (2010) would lead to very many indoor epochs being misclassified as outdoors using the Qstarz GPS data. It is also evident that once outside the Qstarz unit quickly acquires a signal (if signal has been lost whilst indoors), as only 63 or 0.9% of outdoor epochs were missing GPS data. The decision to assign missing GPS data in this study '0' or indoor status therefore results in very few misclassifications of epochs actually recorded outdoors.

This investigation used a convenience sample of eight adult participants in Edinburgh, UK. Use of this threshold in other populations, such as children, may be more acceptable than generalising to other locations. This is because when wearing the GPS receiver, the participant acts as a vehicle for moving the receiver through different locations. Unlike accelerometer or heart rate data, the GPS signal reacts to the environment rather than the wearer. Nonetheless there are complications of using this method which may be exacerbated in youth populations. For example, it is difficult to distinguish signal loss from non-wear time or battery loss and this non-compliance may be more prevalent in youth populations, especially when measurement takes place in free living conditions over a number of days instead of just a few hours. Both non-compliance and removal of the GPS unit for contact sports would likely serve to underestimate time outdoors, as it is reasonable to assume that the unit would be left indoors. The battery life of the unit has a duration of approximately two days and although this represents an improvement on previous technology, the unit would still need to be charged overnight. This represents additional burden which may impact the volume of GPS data recorded, especially towards the end of an observation period.

Although analysis was carried out at an epoch level using pooled data, the present investigation used multiple free living participants as a mechanism to record data in a wide variety of locations. Thus, it is suggested that in order for the observations presented in this chapter to be non-transferable to other populations, those populations would need to visit very different physical environments.

### 6.5.1 Strengths and limitations.

The strength of this work is the comparison of GPS data with known locations using direct observation, which has not been conducted previously. Weaknesses include restriction to a mostly urban environment, and limited wear time for each individual. Observation periods of greater duration would have incorporated more free living activity in a greater variety of locations, however this would have placed considerable burden on the participant. Since GPS signals are affected by physical structures and environmental conditions, it is possible that cities, towns and rural settings may be sufficiently different to alter the threshold. Use of GPS data to determine indoor and outdoor locations should therefore be examined in different settings. It is also questionable whether activity was truly free living, as participants may have adjusted their behaviour due to observation. While some motorised transport was included in the observation periods, further work is required to assess the effect of motorised transport on GPS signals, as some populations may spend considerably more time in cars, buses or trains. Within the field of physical activity research, GPS data are increasingly used to classify accelerometer data, and for this reason it was important to assess the prediction of indoor/outdoor location on an epoch-by-epoch basis using

ROC analysis. However, it may be of interest to those researching time outdoors specifically to examine the GPS prediction of minutes spent outdoors in a larger sample using methods such as Bland-Altman plots.

### 6.5.2 Conclusions.

In conclusion, this chapter demonstrates that the SNR should be used in preference to the RCA for determining indoor and outdoor location. The SNR 212 threshold is suggested for this purpose, with 96.8% of recorded epochs being correctly classified as either indoors or outdoors. This optimal threshold may be useful for those wishing to measure time outdoors, remove indoor data from a dataset intended for GIS analysis, or use GPS to enhance the contextual information provided by diary data (Goodman et al., 2012). The optimal threshold is likely transferable to other populations, however further work should be conducted to test this in different demographic groups and locations.

## 6.6 What Did This Chapter Contribute?

- This chapter demonstrated that SNR data from a GPS receiver can very accurately differentiate the indoor or outdoor location of free living individuals in a variety of urban and suburban environments.
- The high success rate of this method is advantageous for those wishing to investigate time outdoors, match GPS with other data sources, or remove unreliable indoor GPS data.
- Although direct comparisons are difficult, this method likely represents an improvement on the method used to determine indoor or outdoor location used in Chapter 5.

Chapter Seven

# The Profile of Children's Objectively Recorded Indoor and Outdoor Leisure-Time Physical Activity

## 7.1 Abstract

Children's physical activity occurs in multiple contexts; however the profile of how this activity occurs is unclear. This chapter aimed to record whether indoor and outdoor leisure-time physical activity is structured or unstructured, and explore relationships between time spent in these contexts and total daily MVPA.

Participants were 82 children aged 11-13 from four schools in Edinburgh, UK. Between September 2012 and January 2014 physical activity was recorded over seven days using an accelerometer and matched to GPS receiver data. With help from a parent, children reported the times of structured physical activity using a diary. Time spent and MVPA were summarised according to indoor or outdoor location and whether activity was structured or unstructured. Associations between context-specific time spent and total daily MVPA were examined using multivariate linear regression.

Children spent most time and recorded most MVPA at school or in unstructured leisure-time contexts, but spent very little time and recorded very little MVPA in structured leisure-time contexts. Regression analyses suggested that unstructured outdoor leisure-time is associated with an increase in total daily MVPA almost twice that of unstructured indoor leisure-time (*b*-value [95% CI]: 8.45 [1.71, 14.48] vs. 4.38 [0.20, 8.22] minute increase per hour spent). The association was even stronger for time spent in structured outdoor leisure-time (35.81 [20.60, 52.27]).

Research and interventions should focus on strategies to facilitate time outdoors during unstructured leisure-time and maximise MVPA recorded when outdoors. Increasing the proportion of children engaging in structured activity may be beneficial as whilst time spent was limited, association with MVPA was strongest.

## 7.2 Introduction

UK guidelines advise that children aged 5 – 18 should participate in structured and unstructured activities throughout the day to achieve the recommended 60 daily minutes of MVPA (Department of Health, 2011). Whole-of school-programs encouraging structured and unstructured forms of physical activity before, during and after school are also highlighted as one of the seven investments that work for promoting physical activity (GAPA, 2011). During children's leisure-time, structured physical activities are those with elements of formality and are commonly facilitated by adults; sport, dance classes and after school clubs are typical examples (Department of Health, 2011). On the other hand, unstructured leisure-time physical activities such as indoor or outdoor play tend to be child directed, intermittent and informal (Bailey et al., 1995; Brockman et al., 2011a). Children can also obtain physical activity during school-time.

Participation in unstructured physical activity, particularly that which occurs outdoors, is of interest due to the absence of barriers such as cost or need for facilities/equipment, and the high yield of MVPA per unit time (Brockman et al., 2010; Cooper et al., 2010; Mackett & Paskins, 2008). Unfortunately, participation in unstructured outdoor physical activities seems to be restricted for some children. Evidence presented in Chapter Five shows that children spend very little time outdoors with friends. The review presented in Chapter Three suggests that limited independent mobility and parental safety concerns constrict this type of activity, particularly for younger children and girls. Data describing trends over time are scarce, however some authors hypothesise the emergence of a 'backseat generation', who rather than engaging in unstructured outdoor physical activity, are instead transported by car to take part in structured adult-facilitated sport and exercise (Fyhri, Hjorthol, Mackett, Fotel, & Kytta, 2011; Karsten, 2005; Valentine & McKendrick, 1997). Thus whilst a combination of structured and unstructured physical activity has been advocated as a means to help children meet current guidelines, participation levels in physical activity across contexts may vary between individuals and demographic groups. At present the daily profile of children's physical activity engagement is unclear, and as such it is uncertain which contexts should be the subject of intervention efforts.

Exploring the contributions of unstructured and structured contexts of physical activity may be particularly important for children at the transition from primary to secondary school. It is at approximately this age when independence from adults begins to develop, allowing greater access to independent outdoor time (Jago et al., 2009; O'Brien et al., 2000). However, it is also reported that children undergo a shift away from unstructured physical activity with increasing age (Payne, Townsend, & Foster, 2013). In addition to age, evidence reported in Chapter Three also indicates that participation in physical activity in different contexts may be moderated by sex and SES. The balance between structured and unstructured physical activity is therefore complex and at present not well understood.

As discussed in Chapter Three, this lack of clarity may be a result of adult misperceptions of the nature and location of children's unstructured physical activity. Furthermore, these misunderstandings may have been exacerbated by a reliance on self-report to measure the intensity of behaviours that are typically sporadic and unmemorable (Baquet et al., 2007; Kohl et al., 2000). Deconstructing children's leisure-time physical activity into its contextual attributes could provide more detailed information about how, where, when and with whom it occurs. Chapter Five partitioned children's after school time into indoor and outdoor locations, and by who this time was spent with. By combining data from GPS receivers, diaries and accelerometers it was possible to identify the contexts where MVPA occurs. This chapter uses a similar approach to distinguish structured and unstructured leisure-time physical activity, and whether this occurs indoors or outdoors.

It follows that the aim of this chapter is to examine children's structured and unstructured leisure-time physical activity occurring indoors and outdoors. Specifically, this chapter has aims to answer two research questions:

1. What are contributions of these different contexts towards total daily time spent and MVPA?
2. What is the strength and nature of associations between time spent in these contexts and total daily MVPA?

## 7.3 Methods

### 7.3.1 Participants and recruitment.

Participants were recruited via schools due to the relative ease of access to individuals from a variety of backgrounds and diverse physical activity participation levels. Recruitment through clubs or other organisations may increase risk of sample selection bias (Wickel & Eisenmann, 2007), while identifying individual children can prove difficult without the presence of a responsible adult or other gatekeeper (Lewis & Lindsay, 2000). The decision to approach S1 (first year of secondary school) rather than P7 (final year of primary school) children was taken in view of the larger year group size at secondary schools offering a greater pool of children at each site. Before contacting schools, permission was granted by the Children and Families department at The City of Edinburgh Council. Ethical approval was granted by The Moray House School of Education Ethics Committee at The University of Edinburgh.

Twenty-five secondary schools in the City of Edinburgh were invited to take part in the study by email/letter/telephone communication to the head teacher. Four schools were included based upon their willingness to take part. Briefings about the purpose, methods and procedure of the study took place during face-to-face meetings with appointed contact teachers, who on all four occasions were based within the Physical Education department of the school. Three state schools and one independent school agreed to take part. The three state schools were spread across the city geographically and drew from catchment areas with varying levels of deprivation. The independent (day rather than boarding) school was centrally located, charged fees for enrolment and drew from locations throughout the city and outwith the urban area. All data collection took place during term time between September 2012 and January 2014. To maximise ease of return of the study equipment and consistency between weeks of data collection, holiday weekends or mid-term breaks were avoided. Data were collected during summer and winter months as defined by British Summer Time.

Once schools had confirmed their involvement, the researcher subsequently introduced the purpose, methods and requirements of the study to pupils in the S1 year group (11-13 years old) during normal school hours. Contact with children varied with resources and time constraints at each school. One school permitted initial contact with the entire year group (>150 pupils), whereas at other schools this was limited to one or two classes of approximately twenty pupils. Information packs with informed consent forms were offered to interested children on a voluntary basis. The researcher returned the following week to begin data collection with those children who had returned a consent form signed by a parent/guardian and who verbally agreed to take part. No exclusion criteria were set, however some children voluntarily exited the study shortly before commencement due to injury, illness or other unexplained reasons.

### 7.3.2 Measures.

On the first day of data collection all participants involved in the study were supplied with a numbered pack containing: 1) correspondingly numbered belt with identically numbered accelerometer and GPS receiver devices; 2) a charging device for the GPS receiver; 3) instruction sheet with researcher contact details; 4) physical activity diary; and 5) short questionnaire. The contents of the pack were explained fully with demonstration of how the belt was to be worn, and assistance to tighten the belt securely was provided where necessary. Instructions were given to participants to wear the belt with the accelerometer on the right hip and the GPS receiver in a position that felt comfortable. Further instruction was provided with regard to charging of the GPS device using the charger. Participants were requested to wear the belt during all waking hours except when bathing, showering or swimming and advised by both the researcher and teacher to return the pack at the same time and place the following week.

#### *7.3.2.1 Physical activity.*

Physical activity intensity was recorded using an accelerometer (GT3X+; ActiGraph LLC, FL, USA) initialised on a personal computer synchronised to UTC. Participants were asked to wear the accelerometer (3.8 cm × 3.7 cm × 1.8 cm; 27 g) for seven continuous days including two weekend days. The devices were set to record at the default setting of 30 Hz for the entire data collection period. Given the large storage capacity and battery life of the accelerometer, no charging or further alteration was required once distributed to the participants.

#### *7.3.2.2 Indoor or outdoor location.*

Participants were also asked to wear a GPS receiver (Qstarz BT-Q1000eX; Qstarz International, Taiwan, Republic of China) which permits identification of indoor or outdoor location using the SNR as outlined in Chapter Six. This device is larger and heavier than the accelerometer (7.2 cm × 4.7 cm × 2.0 cm; 65 g) but still unobtrusive. The GPS receiver was set to record location every ten seconds (0.1 Hz). During preliminary testing of the device storage capacity, 0.1 Hz was the highest viable frequency for seven days of continuous recording. The device was secured safely in the manufacturer's pouch and concealed with black tape to prevent tampering. Previous testing indicates this device has a battery life of approximately 42 hours (Duncan et al., 2013) and it was therefore necessary for participants to charge the device each night using the charger supplied.

#### *7.3.2.3 Diary data.*

A diary was included in the pack for participants to record the times of participation in structured physical activity such as sports clubs, after school clubs or structured exercise classes. In contrast to unstructured physical activity which is often sporadic and unmemorable, structured physical activity has an element of formality and adult facilitation (Department of Health, 2011), normally occurs within specific timeframes and often reoccurs during the same period each week. Simplifying the diary to record only structured physical activity limited participant burden and in combination with school start and end times permitted the partitioning of structured and unstructured contexts of leisure-time physical activity.

The diary which was based on the tool used in Chapter Five, included examples and was organised by day with separate rows for distinct activities and columns to include the activity name, start time and end time. Participants were asked to complete the diary with the help of their parent(s) or guardian. If a child returned an empty diary, it was confirmed verbally with prompts that they had engaged in no structured physical activity during the data collection period (i.e. did you play any sport? Did you go to any clubs?).

#### *7.3.2.4 Other variables.*

Height (m) and weight (kg) were measured with shoes removed and indoor clothing using a stadiometer (seca 213; seca; CA, USA) and digital scales (seca clara 803; seca; CA, USA). Body mass index was calculated (body mass in kg divided by height in metres squared). One school preferred their pupils to not have height and weight measured. Age, sex, ethnicity and post-code were captured on the physical activity diary with the help of a parent or guardian and missing or unclear data were confirmed by the school secretary where required. Minutes of daylight were determined using standard tables (www.timanddate.com, accessed March 2014), and summer or winter season was defined using British Summer Time. The Scottish Index of Multiple Deprivation (SIMD) 2012 score was defined using full home postcode. The SIMD vigintile was used to aid interpretation (www.scotland.gov.uk, accessed March 2014).

### 7.3.3 Data processing

#### *7.3.3.1 Matching of accelerometer, GPS and diary data.*

Data processing was conducted using STATA (Stata/SE v12.0, Stata Corp. College Station, TX, 2011). Ten second epoch data from the GPS receiver were downloaded using QTravel software (v1.41; Qstarz International, Taiwan, Republic of China). Raw accelerometer data were downloaded using ActiLife software (v5.9.2; Actigraph LLC, FL, USA), with instruction to summarise counts over a ten second epoch to match the epoch of the GPS data. Methodological evidence suggests that using data from ten second epoch accelerometer data provides comparable estimates of MVPA to direct observation, although even shorter epoch durations should be used if possible to minimise error (McClain, Abraham, Brusseau, & Tudor-Locke, 2008), and this is consistent with previous work(Baquet et al., 2007). In this study a ten second epoch was used due to limitations of the recording capacity of the GPS device. The GPS and accelerometer data were matched by date and time stamp using programming script obtained from the University of Bristol.

Each row of combined accelerometer and GPS data was coded as either “school-time”, “leisure-time structured”, or “leisure-time unstructured”. This was achieved using start and end times specific to each school and day of the week to identify school time, and start and end times from the structured physical activity diary to dichotomise leisure-time into structured and unstructured contexts. Rows of data were further categorised as indoors or outdoors using the SNR ratio threshold of 212 as described in Chapter Six.

#### *7.3.3.2 Quality checking of accelerometer and GPS data.*

As described in section 2.5.1, children’s physical activity varies by time of day and day of the week. It was therefore necessary to assess whether participants wore the accelerometer for a duration sufficient to provide a reliable estimate of habitual physical activity and consequently be included in analyses (Rich et al., 2013). This process has three stages. Firstly, periods of non-wear time must be identified and removed from the dataset. Secondly, the duration of daily wear time data required for a recording day to be included in analyses must be established. Finally, a criterion which defines the minimum number of valid recording days necessary for a participant to be included in analyses must be set. Unfortunately, no standard procedures exist; moreover, these steps are typically not well described in the literature (Masse et al., 2005).

*Identification and removal of accelerometer non-wear time.*

Participants were asked to wear the accelerometer and GPS belt for seven continuous days. However, it is often the case in free living physical activity investigations that participants do not wear measurement devices as requested. Accelerometer datasets therefore contain both wear time and non-wear time. Non-wear time includes periods when participants are asked to remove the accelerometer such as sleeping, showering or swimming, but also periods when the accelerometer was removed for unexplained reasons (i.e. non-compliance). Non-wear time presents as strings of zero values in accelerometer output, and thus a simple solution would be to remove zero values from the dataset. However, accelerometer zero values are also representative of wear-time during sedentary behaviours such as sitting or instances of standing still. These are

valuable data which must be retained because non-movement is part of normal behaviour. Distinguishing between non-movement and non-wear time is normally achieved using an automated filter which applies a decision rule on the number and pattern of consecutive zero values (Colley, Connor Gorber, & Tremblay, 2010). The choice of decision rule must be carefully considered however there is little guidance from the literature. Decision rules which exclude periods of consecutive zero values vary from 10 to 180 minutes, often allowing for interruptions. These various definitions systematically over- or under-estimate non-wear time (Choi, Liu, Matthews, & Buchowski, 2011), and this can lead to bias due to variation in sample retention and the quantification of patterns of physical activity behaviour (Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013; Colley et al., 2010). The most commonly used algorithm recognises 60 minutes of consecutive zero values as non-wear time allowing for up to two minutes of non-zeroes per hour (Choi et al., 2011; Troiano et al., 2008). This decision rule has been validated using uni-axial accelerometers such as the Actigraph GT1M (GT1M; ActiGraph LLC, FL, USA) which was used in Chapter 5.
Validation studies suggest that while there may be differences in vertical counts for some activities, these devices are essentially comparable when seeking to classify overall energy expenditure or time spent in different intensity categories (Hanggi et al., 2013; Jimmy, Seiler, & Mäder, 2013).However, the validity of non-wear time algorithms is distinct from the issue of comparability of accelerometer count output. Algorithms validated using uni-axial accelerometers may not be applicable to tri-axial accelerometers which are sensitive to movement in multiple planes. At the time of writing, there is no evidence of the validity of different wear-time algorithms in this age group. One peer-reviewed study has examined non-wear time using waist-mounted tri-axial accelerometry (Actigraph GT3X), however study used an adult population. This study reports that removing 60 minutes of consecutive zeroes, with no allowance for interruptions, results in the least misclassification of non-wear time (Peeters, van Gellecum, Ryde, Farias, & Brown, 2013). In addition, whilst it is common for investigators to ask participants to record wear time in a diary, this study also suggests that automatic filters for detecting non-wear time are as accurate as a combination of log book and automatic filter (Peeters et al., 2013). Given the limited benefit and greater burden associated with this task which may be amplified in child

populations, participants were not asked to record a wear time log. Instead, an automatic filter identifying 60 minutes of consecutive zero values as non-wear time was used to predict and remove periods when the accelerometer was not worn.

*Definition of minimum wear time.*

Once non-wear time has been predicted and removed, valid wear time can be summed to calculate the total daily wear time. The reliability of estimates of habitual physical activity is proportional to the hours of daily wear time and number of days of monitoring (Rich et al., 2013). The minimum daily wear time is a criterion set to determine whether the accelerometer has been worn sufficiently to depict the daily pattern of activity. This threshold for minimum daily wear time must be high enough to eliminate days on which the accelerometer was not worn, but low enough to prevent valuable days of data being removed, which may reduce sample size and introduce bias (Colley et al., 2010; Rich et al., 2013). Unfortunately no single criterion has been used; in fact, 13 or more definitions have been identified ranging from ≥ 4 hours per day to ≥ 12 hours per day, with thresholds between ≥ 8 and ≥ 10 hours most commonly used (Cain et al., 2013; Rich et al., 2013). Consistent with other work that has combined full day accelerometer and GPS data in youth populations (Klinker et al., 2014a) this study used a criterion of ≥ 9 hours of wear time. Days which did not meet this criterion were removed from the dataset.

*Definition of required number of valid measurement days.*

The number of valid days of accelerometer data required for individual participants to be included in analyses also varies between studies. Four or five days of monitoring have been recommended to provide a reliable estimate of the pattern of physical activity (Trost, Pate, Freedson, Sallis, & Taylor, 2000b), however this is not a consensus position with diverse criteria between ≥ 1 and ≥ 10 days reported (Cain et al., 2013). This study recorded physical activity over 7 days with the intention that participants would provide at least three week-days and one weekend-day of valid data (i.e. nine hours of wear time on at least four days). Recent evidence suggest that these inclusion criteria result in high reliability (r = 0.93) for accelerometer measured habitual physical activity (Rich et al., 2013), while additional research reports that such criteria would result in a participant retention rate of 94.1% (Toftager et al., 2013).

*Management of erroneous data.*

The first day of measurement was removed for all participants due to risk of reactivity bias and variation in the time of commencement of the study. Spuriously high accelerometer counts were removed based upon a threshold of 15000 counts per minute (Esliger, Copeland, Barnes, & Tremblay, 2005). Data points with high speed (> 15 km/h) were removed as being motorised transport (Cooper et al., 2010). The GPS unit does receive signals when indoors and participants were instructed to charge the device to maintain battery life. Despite this, some GPS epochs were missing so these were assumed to be indoors and missing SNR data were replaced with a value of zero.

#### *7.3.3.3 Outcome variables.*

Each ten-second epoch of combined accelerometer, GPS and diary data was coded as one of five contexts. Each epoch was also classified as MVPA when counts exceeded 560 per ten seconds (Hanggi et al., 2013). This coding strategy is summarised in Table 7.1. Once rows of data had been coded in this way it was possible to sum minutes of time spent and MVPA in each context by participant and day. Based on individual means across days of measurement, week-day and weekend-day scores were calculated for overall daily MVPA, context-specific MVPA and context-specific wear time.

Table 7.1 *Source of data and decision rules for creation of context-specific physical activity outcome variables.*

| | Source of data and decision rule | | |
|---|---|---|---|
| Outcome variable | GPS | Diary | Accelerometer |
| Unstructured outdoor MVPA | SNR ≥ 212 | No entry | > 560 counts per ten second epoch |
| Unstructured indoor MVPA | SNR < 212 | No entry | > 560 counts per ten second epoch |
| Structured outdoor MVPA | SNR ≥ 212 | Structured physical activity reported | > 560 counts per ten second epoch |
| Structured indoor MVPA | SNR < 212 | Structured physical activity reported | > 560 counts per ten second epoch |
| School MVPA | Not applicable | Specified by school timetable | > 560 counts per ten second epoch |

*Abbreviations*: Moderate to vigorous physical activity (MVPA); Global Positioning System (GPS); signal-to-noise ratio (SNR).

### 7.3.4 Data analyses.

All data analyses were conducted using SPSS (IBM SPSS Statistics, v19.0, SPSS Inc., Chicago, IL, 2010). One way analysis of variance was used to assess differences in estimates of overall daily MVPA per participant according to number of valid week-days of monitoring (one day – four days). Kruskal-Wallis tests were used to examine relationships between number of valid week-days of monitoring (1-4) and context-specific MVPA. Since there were no significant differences in estimates of overall daily MVPA ($p = 0.91$) or context-specific MVPA ($p = 0.77$–$0.86$) by number of valid days of measurement, all participants who recorded at least one valid day with 9 hours recording time were included in analyses. Independent samples t-tests and Pearson chi-squared tests were used to examine differences between included and excluded participants, and differences between children who did and did not provide valid weekend-day data.

Means (with standard deviations in parentheses) and percentages were used to examine total daily wear time, total daily MVPA and demographic characteristics. Owing to non-normal distributions, the median and interquartile range (IQR) were used to assess absolute (minutes) and relative (percent) context-specific contributions to daily wear time and daily MVPA on week-days and weekend-days.

Due to limited data provided on weekend-days, relationships between time spent in specific contexts and total daily MVPA were assessed only for week-days. A multivariate linear regression model was used to assess associations between time spent in each of four leisure time contexts and total week-day MVPA. This was expressed as the mean increase in minutes of MVPA for each hour of wear time in that context after adjusting for wear time spent in all other contexts. Bivariate associations of potential confounders (age, sex, SIMD, daylight hours) identified in Chapter Three with independent and dependent variables were tested using Pearson correlation coefficients. Potential confounding factors were included in the model if they were found to be associated with both the predictor and outcome. This likelihood of confounding was assessed by examining the strength of associations and use of a more inclusive criterion for the alpha-level of $p < 0.20$ (Maldonado & Greenland, 1993). In addition, the presence of confounding was assessed by comparing unadjusted and adjusted regression coefficients. Factors which resulted in adjusted coefficients differing from unadjusted coefficients by ten percent or more were retained in the model (Maldonado & Greenland, 1993). School-time was not expected to vary between children and consequently was not included in the model. Hypothesising a large effect ($R^2 > 0.26$) and with a maximum of eight predictors, the sample size for this study was appropriate to achieve power of 0.80 (Cohen, 1988; Field, 2013). Contextual predictor variables were $\log_{10}$ transformed to achieve a normal distribution. However, since there were no differences between models using transformed and untransformed data, untransformed results are shown for clarity.

## 7.4 Results

### 7.4.1 Wear time on week-days and weekend-days.

Of the 82 children who agreed to take part, 70 provided at least 9 hours of accelerometer data on at least one measurement day. A mean of 3.1 (1.3) valid days of data were provided per participant. Valid week-day data were recorded by 70 participants. A mean of 2.7 (1.1) week-days per participant with a mean of 11.3 (1.4) hours of wear time per day were provided. However, only 27 participants recorded valid data on at least one weekend-day. This subset of participants provided a mean of 1.2 (0.4) weekend-days per participant with a mean of 12.9 (4.1) hours of wear time on those days. No participants supplied weekend-day but not week-day data. Valid GPS data were present for time matching to a high proportion (> 99.9%) of valid accelerometer epochs.

### 7.4.2 Sample characteristics.

The final sample consisted of 23 boys and 47 girls of mean age 12.4 (0.4) years. The 57 children who provided height and weight measurements had a mean BMI of 18.7 (2.5) kg/m$^2$. Of the included participants, 91.4% were white and 62.9% attended an independent school. On average participants resided in areas within the 16$^{th}$ vigintile for SIMD (compared to the 14$^{th}$ vigintile for the City of Edinburgh; www.scotland.gov.uk, accessed March 2014). Compared to participants included in analyses, those who failed to meet inclusion criteria did not differ by sex, age, ethnicity, SIMD, BMI or school attended ($p$ = 0.15–0.97). Participants that provided weekend data (n = 27) did not differ from those who did not (n = 43) by these same characteristics ($p$ = 0.33–0.77).

### 7.4.3 Overall physical activity.

The children recorded a mean of 67.6 (25.8) minutes of MVPA on week-days, with 60.0% of the participants meeting the Department of Health recommendation of one hour of MVPA per day (Department of Health, 2011). On weekend-days a mean of 62.9 (36.9) minutes of MVPA were recorded, with 48.1% of participants recording at least one hour. Of the 70 children who met inclusion criteria, 31.4% recorded no structured physical activity during the measurement period.

### 7.4.4 Context-specific time spent and MVPA on week-days.

Table 7.2 shows median minutes recorded per participant during school-time and during the four leisure-time contexts. Also presented are the median percent contributions toward total daily time. Children spent most time at school, followed by periods spent indoors during unstructured leisure-time. Of all 70 participants, 45.7% recorded no structured physical activity of any kind on week-days, and this is reflected in the median contributions of organised leisure-time physical activity, either indoors or outdoors. In contrast, approximately 80 minutes of unstructured outdoor time were recorded per participant per week-day.

Context-specific contributions towards total daily MVPA are also displayed in Table 7.2, and exhibit a similar pattern to actual time spent, with most minutes being recorded at school, followed by unstructured indoor MVPA and unstructured outdoor MVPA. As a median for all participants, organised indoor MVPA and organised outdoor MVPA appear to contribute very little toward daily totals, although the upper limits for the IQRs indicate that in particular organised outdoor physical activity is a substantial source of MVPA for some children.

Table 7.2 *Context-specific time spent and MVPA per participant per week-day (n = 70).*

| | School-time | Unstructured outdoor leisure-time | Unstructured indoor leisure-time | Structured outdoor leisure-time | Structured indoor leisure-time |
|---|---|---|---|---|---|
| Total minutes recorded | 333.2 (298.8 – 352.1) | 79.8 (50.3 – 114.3) | 235.8 (181.8 – 292.7) | 0.5 (0.0 – 27.0) | 0.6 (0.0 – 12.4) |
| Percent of all daily minutes | 47.2 (40.5 – 53.2) | 11.7 (0.8 – 16.2) | 35.2 (27.3 – 43.0) | 0.1 (0.0 – 4.3) | 0.1 (0.0 – 1.7) |
| Minutes of MVPA recorded | 24.2 (18.9 – 30.7) | 12.2 (5.7 – 22.5) | 14.1 (8.4 – 25.9) | 0.0 (0.0 – 7.1) | 0.0 (0.0 – 0.9) |
| Percent of all daily MVPA | 42.1 (29.7 – 50.0) | 18.2 (11.0 – 31.8) | 24.6 (13.9 – 40.41) | 0.0 (0.0 – 12.5) | 0.0 (0.0 – 1.4) |

*Abbreviation*: Moderate to vigorous physical activity (MVPA).

*Note:* Figures presented are median (interquartile range) per participant per week-day.

### 7.4.5 Associations between time in specific leisure-time contexts and MVPA on week-days.

Hypothesised confounders age and SIMD demonstrated weak non-statistically significant ($p > 0.20$) bivariate correlations with independent and dependent variables, and were not included in the regression model. Male sex demonstrated weak to moderate associations with total week-day MVPA (r = 0.343, $p = 0.002$) and time spent in structured indoor contexts (r = -0.207, $p = 0.043$). Daylight hours demonstrated weak association with total week-day MVPA (r = 0.168, $p = 0.082$) and moderate association with time spent in structured outdoor contexts (r = -0.305, $p = 0.005$). Unadjusted and coefficients adjusted for sex or daylight hours differed by more than 10% for all predictor variables. In the absence of evidence to suggest they are on a casual pathway between the predictor and outcome variables, sex and daylight hours were retained in the regression model.

Table 7.3 shows the output from the multivariate linear regression model examining relationships between hours spent in specific leisure-time contexts and minutes of total week-day MVPA. The model explained 40.8% of the variance in total week-day MVPA. Participation in structured outdoor physical activity was most strongly associated with physical activity, indicating an additional 35 minutes of MVPA per day for every hour spent in that context. Time spent in structured indoor contexts did not make a significant contribution to the model. Leisure-time spent in unstructured outdoor contexts was associated with an increase in daily MVPA almost double that of unstructured indoor contexts, and both predictors made significant contributions to the model.

Table 7.3 *Multivariate linear regression model of hours spent in four leisure-time contexts and minutes of week-day MVPA (n = 70).*

| | *b*-value | 95% CI | | t | *p* |
|---|---|---|---|---|---|
| Unstructured outdoors | 8.26 | 2.85 | 13.66 | 3.05 | 0.003 |
| Unstructured indoors | 4.19 | 0.47 | 7.91 | 2.25 | 0.028 |
| Structured outdoors | 34.67 | 18.09 | 51.25 | 4.18 | < 0.001 |
| Structured indoors | 8.71 | -11.26 | 28.67 | 0.87 | 0.387 |
| | | | | | $R^2 = 0.408$, $p < 0.001$ |

*Abbreviation*: Moderate to vigorous physical activity (MVPA).

*Note*: Adjusted for sex and daylight hours. *b*-value: mean increase in minutes of daily MVPA for each hour spent in that context.

### 7.4.6 Context-specific time spent and MVPA on weekend-days.

Table 7.4 shows median minutes recorded per participant during the four leisure-time contexts on weekend-days. In the absence of school-time, most time was spent as indoor unstructured leisure-time. Approximately one quarter of children's time on weekend-days was spent in unstructured outdoor contexts. Of the 27 participants who provided valid weekend-day data, 51.9% recorded no structured physical activity at the weekend and this is reflected in the low median proportions of time spent in indoor and outdoor structured leisure-time contexts.

Context-specific contributions of MVPA on weekends are shown in Table 7.4. Almost all weekend-day MVPA is split between unstructured indoor MVPA and unstructured outdoor MVPA. As a median for all participants, structured indoor MVPA and structured outdoor MVPA appear to contribute very little toward daily MVPA, although the upper limit for the IQR indicates that some children record a large proportion of their weekend-day MVPA in this context.

Table 7.4 *Context-specific time spent and MVPA per participant per weekend-day (n = 27).*

| | Unstructured outdoor leisure-time | Unstructured indoor leisure-time | Structured outdoor leisure-time | Structured indoor leisure-time |
|---|---|---|---|---|
| Total minutes recorded | 181.7 | 460 | 0.0 | 0.0 |
| | (135.3 – 250.2) | (423.0 – 553.8) | (0.0 – 60.2) | (0.0 – 0.3) |
| Percent of all daily minutes | 25.6 | 67.7 | 0.0 | 0.0 |
| | (18.5 – 34.7) | (58.3 – 77.1) | (0.0 – 9.2) | (0.0 – 0.1) |
| Minutes of MVPA recorded | 16.3 | 23.7 | 0.0 | 0.0 |
| | (9.1 – 35.8) | (13.8 – 40.8) | (0.0 – 23.2) | (0.0 – 0.0) |
| Percent of all daily MVPA | 39.0 | 44.3 | 0.0 | 0.0 |
| | (19.6 – 48.8) | (26.0 – 66.0) | (0 – 26.5) | (0.0 – 0.0) |

*Abbreviation*: Moderate to vigorous physical activity (MVPA).

*Note:* Figures presented are median (interquartile range) per participant.

## 7.5 Discussion

This study combined accelerometer, GPS receiver and diary methods to record context-specific contributions and associations between total daily time spent and total daily MVPA. This detail-rich dataset provides valuable insight in to how children obtain their physical activity throughout the day, and which contexts may be targeted to improve participation in MVPA. The main findings of this study are that in a sample of first year Scottish secondary school children, who on average appeared to meet current physical activity guidelines, school-time and unstructured leisure-time (both indoors and outdoors) accounted for the vast majority of daily MVPA. In comparison, the contributions of structured leisure-time contexts to daily MVPA were minimal. Despite this limited contribution overall, multivariate regression analysis revealed that compared to other contexts, time spent in structured outdoor contexts was most strongly associated with total daily MVPA. Weekend-day data indicated that in the absence of school-time, approximately three hours were spent in unstructured outdoor contexts, which is encouraging given the potential benefits of time outdoors over time indoors. However only a very limited number of children provided data on at least one weekend-day, and although this subgroup of children did not differ from the rest of the sample by demographic variables, it is difficult to draw conclusions which could be generalised from this limited data.

The finding that children spent few minutes per day in structured physical activity contexts and that these periods contributed little towards daily minutes of MVPA echoes previous research using Health Survey for England data (Payne et al., 2013). The proportion of children recording participation in structured physical activity closely matches reports from the Scottish Health Survey, which indicated that 69 % of Scottish children aged 2 - 15 engaged in sport in the previous week (Active Healthy Kids Scotland, 2013). The median percent of daily MVPA occurring in structured contexts was very small; however it is likely that these contributions are underestimated owing to accelerometer non-wear during swimming and contact sports. In this study, diary records were used to add contextual detail to accelerometer data. If no accelerometer data were present, then diary data were not otherwise accounted for. This likely led to underestimation of time and MVPA in structured contexts in three ways: 1) reduction of time spent and MVPA recorded in structured contexts on valid days of accelerometer recording; 2) exclusion of days with marginally insufficient wear-time due to removal of the device during structured contexts; 3) exclusion of days with insufficient wear time due to wearing of the device only during structured contexts with minimal wear-time during the rest of the day (i.e. unstructured and school contexts). Inspection of the dairy data indicates that the majority of the excluded diary data was recorded during swimming rather than removal of the device during contact sports. This approach of using accelerometry as the primary measure, with diary data only serving a secondary role of providing contextual data is therefore limited when attempting to record certain types of physical activity. This may be particularly the case when attempting to characterise context-specific behaviours that are more irregular than habitual physical activities, for example such as daily active commuting or recess. Data processing steps and thresholds for wear-time may cause valuable data to be discarded. Future work should therefore explore the possibility of further integration of diary and accelerometer data. For example, normative data from the Compendium of Physical Activities (Ainsworth et al., 2011) could be used to indicate physical activity intensity when diary data are present and accelerometry is missing. This approach would likely present further complications but could perhaps be preferable to losing otherwise usable data.

There may be alternative explanations for the small percentage of daily MVPA occurring in structured contexts Independent schools also have a tradition of student participation in team sports and extracurricular activities occurring within school-time. Additional team sports and organised activities during school-time may have inflated the contribution of MVPA during school-time at the cost of structured-leisure-time contexts. The IQRs indicate that some children do have better access to structured physical activity and for these individuals this context is an important source of MVPA. This is particularly evident on weekend-days when participation in structured activities such as team sports may be more likely to occur. Even for those children who did report structured physical activity, the frequency and duration of these activities was limited with many only reporting one or two hours on a single day of measurement. The additional MVPA accrued for each hour in structured outdoor physical activity highlights this context as a potentially fruitful intervention target, and in particular, increasing the frequency of sessions may be beneficial. However, encouraging participation in structured physical activity in children who are more inactive and deprived than those represented by this sample may be a significant challenge, especially given limited investment in after school sport, and that competitive sports-oriented opportunities do not suit many children's preferences (Allender, Cowburn, & Foster, 2006; Weiler, Allardyce, Whyte, & Stamatakis, 2014). Furthermore, the above estimation of the MVPA benefit associated with an increase in structured outdoor time warrants further discussion. As described in Chapter 5, the extrapolation the MVPA accrued during very little time spent in this context to periods of an hour or more may not be justified, because the relationship between time spent and MVPA may not be linear. This being said, the majority of records in the structured physical activity diary were standardised blocks in multiples of one hour. It must also be noted that the sample estimates for time in this context are a result of: 1) taking the mean across multiple days of measurement, including days when no time in this context occurred; and 2) taking the median for all participants, including those children who recorded no time in this context on any day. This means that whilst the median values reported are very small, this is a result of attenuation from periods of one hour or more due to division across days and participants with zero values. Since the MVPA data recorded during structured outdoor contexts is sourced from organised sessions commonly of a prescribed duration of one or more hours, it may be more acceptable to re-scale in order to assess the impact of the findings of this regression model, than for the models in Chapter 5 where contextual information was not reported in uniform blocks.

The majority of children's MVPA occurred during school-time or unstructured leisure-time. This is in agreement with the work of Maddison et al. (2010) who used GPS and accelerometry to describe the geographic location of children's MVPA, observing that this was mostly centred on school and home locations. The present study showed that during leisure-time, unstructured indoor contexts were how children spent the majority of time and how they recorded most MVPA. This reflects the findings of Chapter Five and those of previous work indicating that indoor leisure time is a vital contributor of

MVPA (Cooper et al., 2010). However, children also spent over an hour in unstructured outdoor leisure-time contexts. This was unexpected, given that independent outdoor time is thought to be restricted for today's children (Fyhri et al., 2011; Karsten, 2005; Valentine & McKendrick, 1997), and that the majority of data collection occurred during winter months when outdoor time is less common (Cleland et al., 2008; Cooper et al., 2010; Wen et al., 2009). The median minutes of unstructured outdoor time recorded in this sample are encouraging and show that access to the outdoor environment may not be as restricted for this sample. Furthermore, these periods were almost twice as strongly associated with daily MVPA than the indoor equivalent, again reinforcing the importance of outdoor time for physical activity. Despite this, the strength of association between unstructured outdoor time and daily MVPA was weaker than expected (8 additional minutes of MVPA per day for each hour spent), and certainly weaker than associations reported in Chapter Five between daily MVPA and time outdoors with other children. The finding that periods spent in structured outdoor contexts were much more strongly associated with MVPA than unstructured outdoor contexts is also in conflict with previous work (Mackett & Paskins, 2008).

These inconsistencies are likely explained by the way in which leisure-time was dichotomised and the resulting broad definition of "unstructured outdoor contexts". This was purposefully employed to capture the fuller range of children's behaviours, some of which may have gone unreported in previous studies. Previously the activity intensity of informal behaviours such as active play has been questioned, especially when self-report measures have been used in isolation. For example, Brockman et al. (2011a) reported that some children identified behaviours such as chatting, computer games or hanging out with friends as 'active' play. The findings of the present study support this work, suggesting that children's unstructured outdoor leisure-time contains a higher proportion of MVPA than when indoors, but that it must also include large portions of sedentary behaviour and light physical activity. Therefore, whilst fostering social and physical environments that encourage children to be outdoors may be key intervention targets, strategies to maximise MVPA once children are outdoors should also be pursued. Further exploration of the context of children's outdoor time is warranted so that we may understand which environments are most supportive of MVPA. In addition, whilst research on sedentary behaviours has typically focused on indoor TV or video game use, this dataset also presents the likelihood of outdoor sedentary time, and this too may be an area worthy of further exploration. As shown here, the use of GPS information adds contextual detail to accelerometer data, and more complex analyses are already being conducted to show which geographic locations are most supportive of physical activity (Jones et al., 2009; Klinker, Schipperijn, Kerr, Ersboll, & Troelsen, 2014b; Wheeler et al., 2010). These more sophisticated techniques will continue to provide greater understanding of the location of children's behaviour, but still fail to capture some contextual detail. This information must instead come from self- or proxy-report, and the merging of diary data to describe the structured or unstructured nature of physical activity is a key strength of this research.

On average, the children in this study met the 60 minute target for daily MVPA. This MVPA was distributed across multiple contexts, but alone, not one of the contexts contributed enough MVPA for children to be sufficiently active. Whole-of-school programs supporting structured and unstructured opportunities before, during and after school are advocated as one of the seven investments that work for physical activity (GAPA, 2011). This unique dataset provides estimates of the contributions of school-time, plus structured and unstructured leisure-time contexts towards daily accelerometer recorded MVPA, and provides further detail as to whether this occurs indoors or outdoors with integration of GPS data. Since intervention strategies will need to be context-specific but also composed of multiple components, this information is important as it provides guidance as to where and when improvements may be needed, and what level of benefit to daily minutes of MVPA could be expected. Potential imbalances in the physical activity profile of children contributing to low MVPA levels have been previously suggested, for example restricted unstructured outdoor time in favour of structured physical activity. Data presented here do not support this hypothesis, and this is common with self-report data from a nationally representative sample in England (Payne et al., 2013). In fact, present results suggest a potential imbalance in the opposite direction, with structured physical activity contributing very little towards daily MVPA even in an active and relatively affluent sample of children that might be expected to participate more often in sports clubs, classes and after school activities led by adults. This is surprising, especially considering that the sample were predominantly female and from more wealthy backgrounds, characteristics of those who have been previously reported to have more restricted outdoor time (Aarts et al., 2010; Brockman et al., 2009; Thomson & Philo, 2004; Valentine & McKendrick, 1997). The profile of children's physical activity is complex, and is moderated by factors such as sex, age, SES and urban/rural location. This complexity underlines the importance of accurate measurement of MVPA and the various contexts in which it occurs. It should also be noted that the children in this sample were relatively homogenous in terms of activity levels (high) and deprivation (low), and this may mask context-specific barriers to physical activity (such as those described in Chapter Three) for children in the wider population.

### 7.5.1 Strengths and limitations.

The work presented in this chapter has a number of strengths, and in particular some methodological improvements on the work presented in Chapter Five. The combination of three sources of data has allowed detailed analysis of the contexts of children's physical activity in a way that has not been performed previously. Of particular importance is the use of whole-day accelerometry, which has allowed the contributions of different contexts to total daily MVPA to be estimated and produces a unique physical activity profile. This is in contrast to the work in Chapter Five which presented only after school data. Whilst there are no reported differences between uni-axial and tri-axial accelerometry (Hanggi, Phillips, & Rowlands, 2013), the tri-axial methods used here represent a theoretical improvement in measurement precision as movement rarely occurs in one plane. As is always the case, the use of accelerometry does not record swimming and underestimates the contributions movement during activities such as cycling, upper body exercise and load-bearing, and this must be considered when viewing these results.

The GPS receiver used in this study offers several research advantages. Studies using older GPS receivers have been hampered by problems such as slow connectivity and signal drop out whilst indoors or near large physical structures (Kerr et al., 2011). The absence or presence of signal can be used to estimate indoor and outdoor time, and this method using the Garmin device (Foretrex 201, Garmin, Schaffhausen, Switzerland) has been used in Chapter Five as well as previous work (Cooper et al., 2010; Wheeler et al., 2010). Direct comparisons are difficult, however the GPS receiver used in present study has demonstrated very limited signal loss, and this means that a very large proportion of valid accelerometer epochs were successfully matched to a GPS record. This proportion of matched data offers greater confidence in the estimation of indoor or outdoor location using the SNR method described in Chapter Six. However, some misclassification is likely and in particular time in motorised transport may have been erroneously classified as time outdoors. Steps were taken to remove GPS data with high speed; however periods spent in slower traffic may have led to overestimation of the total time children spend outdoors. Other sources of misclassification will also be present, however as shown in Chapter Six, use of the SNR to determine indoor or outdoor location can be up to 97% accurate in free living individuals. The very large proportion of matched GPS and accelerometer data also demonstrates that this group of children were capable of following instructions to charge the GPS unit using the charging device provided. These findings are promising for future studies which seek to use GPS data to determine geographic location in child populations.

Whilst mean days of measurement per participant are comparable to studies using similar methods in children of approximately the same age (Klinker et al., 2014a), the findings of this chapter are limited by inclusion of children with only one valid day of monitoring. Typically, four or five days of measurement are deemed to be sufficient to provide a reliable estimate of children's habitual physical activity (Trost et al., 2000b). In this study, there were no differences in mean daily MVPA or context-specific MVPA by number of valid days of measurement, and so all children providing at least one day of measurement were retained to maximise an already limited sample size. As noted by Klinker at al. (2014b), it is presently unclear how many days of measurement are required to obtain reliable estimates of context-specific physical activity. This may be a particular concern for structured physical activity which appears to occur less frequently and at specific timetabled slots each week. Developing inclusion criteria for this type of work was outside the scope of this thesis, however increasing focus on context-specific behaviours and determinants highlights further methodological research on the design of studies combining GPS and accelerometry as a clear priority. Additional weaknesses of this work include the small sample size which precluded stratification by sex and a relative lack of weekend data which has precluded full analysis of activity on those days. Furthermore, due to logistical restraints analyses are limited to term-time only data and cannot be generalised to school holidays when activity during some contexts, such as outdoor play or organised sports camps may be greater. A large proportion of children attended an independent school and the mean daily minutes of MVPA does indicate selection bias. Findings should therefore be treated with caution, as the physical activity profile reported may not be generalisable to the wider population. In particular, it could be expected that the general population has even lower involvement in structured physical activity than children from less deprived neighbourhoods (Maher & Olds, 2009; Payne et al., 2013), and not obtain as many minutes outdoors as the active children measured here. It is therefore important to reproduce this work in larger samples, particularly with the inclusion of children from more disadvantaged areas and schools.

In common with most studies which use subjective methods to measure physical activity, there may be errors in the children's report of their activities and consequent MVPA classification (Goodman et al., 2011). The purpose of the study was to examine structured and unstructured physical activities, and by asking children to record only structured activities, leisure-time was dichotomised. It is possible that some structured activities may have gone unreported, however due to the nature of these activities (they tend to occur at regular times) and the fact that parents were requested to help complete diaries, errors may have been minimised. Steps were also taken to ensure empty dairies were representative of children's actual pattern of behaviour. Whilst it has not been possible to validate the diary method used, the fact data very closely match self-report data from Scottish Health Survey is encouraging (Active Healthy Kids Scotland, 2013). Although the dichotomisation of leisure-time was based on terminology and categories used by both GAPA (2011) and the Department of Health (2011), this may be a simplification and ignores the possible existence of semi-structured activity or further subcategories of behaviour. This further demonstrates the complexity of measuring the type and context of physical activity and reinforces the need for further work investigating the social and physical environments children encounter.

### 7.5.2 Conclusions.

The research reported in this chapter used a novel multi-method approach to investigate the source of children's MVPA throughout the day. The results suggest that strategies to increase MVPA should target multiple contexts and that specific improvements may be required in three areas: 1) increasing the proportion of children participating in structured leisure-time physical activity (especially outdoors), plus the duration and frequency of these sessions as they are highly conducive to MVPA; 2) maximising the time children spend outdoors during unstructured leisure-time; 3) developing environments or opportunities that facilitate greater MVPA participation once children are outdoors.

### 7.6 What Did This Chapter Contribute?

- Accelerometer, GPS and diary data collected over a period of seven days indicated that on average children recorded more than the current 60 minutes recommendation for MVPA, and that this MVPA was recorded cross multiple contexts, with no single context fulfilling the target alone.
- Children spent most time and recorded most MVPA at school or in unstructured leisure-time contexts. Conversely, children spent very little time and recorded very little MVPA in structured leisure-time contexts.
- Multivariate regression analyses suggested that structured outdoor leisure-time was most strongly associated with daily minutes of MVPA. Compared to unstructured indoor leisure-time, unstructured outdoor leisure-time was almost twice as strongly associated with daily MVPA.
- Results indicated that whilst children are more active when outdoors compared to indoors, much of unstructured outdoor leisure-time is spent as light activity and sedentary behaviours. Future research should seek to better understand children's time outdoors during unstructured leisure-time and investigate potential intervention mechanisms to maximise MVPA.

# Chapter Eight
# **Conclusions**

## 8.1 Introduction
This concluding chapter begins by presenting the main findings of the research project. Next, implications of these findings are discussed and reflected upon. Limitations of the research as a whole are then examined, and finally, recommendations are made for future research.

## 8.2 Main Findings
### 8.2.1 Correlates and determinants of children's outdoor play: a review of the literature.
Chapter Three reviewed the individual, social-cultural and physical-environmental factors related to children's outdoor play. Thirty-one quantitative, qualitative and mixed-methods studies were reviewed to understand the correlates and determinants of children's participant in this behaviour. Males, younger children and those from lower SES backgrounds appear to engage in more outdoor play than their counterparts. The following social-cultural and physical-environmental factors were found to be most consistently related to greater outdoor play: greater independent mobility, greater parental perceptions of safety, greater neighbourhood social cohesion, greater availability of other children to play with, and living in a cul-de-sac neighbourhood design. In addition, the strength and direction of many relationships appeared to be moderated by age, sex, SES and season. The review, and in particular the qualitative evidence, revealed knowledge gaps about how, where and with whom children use different indoor and outdoor leisure-time contexts, and the extent to which these periods are spent in MVPA. Based upon the outcomes of this review, the overall aim of the thesis was refined in Chapter Four.

### 8.2.2 Who children spend time with after school: associations with objectively recorded indoor and outdoor physical activity.
Chapter Five used previously collected data from a sample of 427 boys and girls aged 10-11 years from Bristol to investigate whether who indoor and outdoor time was spent

with was associated with after school MVPA. The main findings were that children spent most of the after school period with their mum/dad or alone, especially when indoors. However, when children were outdoors more time was spent with friends than other people or alone. Multivariate regression analyses suggested hours outdoors with friends were positively associated with minutes of MVPA for both sexes. Time spent alone was not associated with MVPA regardless of sex or indoor/outdoor location.

### 8.2.3 Indoors or outdoors? Examining the use of GPS data to differentiate physical activity location.

Chapter Six investigated whether or not GPS data could be used to distinguish indoor and outdoor locations, with a view to matching this information with accelerometer output to describe this contextual attribute of physical activity. It was shown that use of the SNR was superior to use of the RCA to differentiate indoor/outdoor location. This was evident when inspecting the respective ROC curves, comparing the area under the ROC curves statistically, and when comparing the overall number of epochs of indoor and outdoor time that were correctly classified. Using a cut point of 212, the SNR correctly classified 96.8% of epochs with sensitivity of 0.960 and specificity of 0.970. Using the criteria of Metz (1978), the SNR was shown to have ‘‘excellent’’ discriminating ability. The finding that misclassifications are limited using this methodology is important as this affords researchers confidence in the estimates of time spent indoors and outdoors derived from GPS data.

### 8.2.4 The profile of children’s objectively recorded indoor and outdoor leisure-time physical activity.

Chapter Seven categorised children’s leisure-time into structured and unstructured contexts, and further partitioned these periods into indoor and outdoor locations. Whole-day accelerometry allowed the context-specific contributions towards total daily time and MVPA to be explored. The main findings of the study were that in a relatively active and affluent sample of 11-13 year olds, children accumulated most of their MVPA in school-time or unstructured leisure-time contexts (both indoors and outdoors). Surprisingly for the sample concerned, the contributions of structured leisure-time contexts to daily MVPA were minimal. Despite this limited contribution overall, multivariate regression analysis revealed that compared to other contexts, time spent in structured outdoor contexts was most strongly associated with total daily MVPA. Children spent over an hour per day in unstructured outdoor contexts, however the association with total daily MVPA was weaker than expected.

## 8.3 Implications

This thesis contributes to research in the field of children's context-specific physical activity, both in terms of the actual findings, but importantly also by developing and implementing novel methods to successfully characterise physical activity in this population. Different physical activity behaviours have different determinants and health benefits (Caspersen et al., 1985; Giles-Corti & King, 2009) and likely vary in their overall impact on children attaining the recommended daily minutes of MVPA. Considering the contextual attributes of physical activity is therefore critical to design interventions with the best chance of changing behaviour (Bauman et al., 2012; Sallis et al., 2000a). This understanding relies upon a method that can not only record these contextual attributes, but also the type and intensity of physical activity that is occurring. As described in section 4.2, this is a complex task as no single method can record all dimensions of physical activity.

This research therefore contributes to current understanding in three areas, and these implications are set out in greater detail in sections 8.3.1 to 8.3.3:

1. Exploring an approach to categorise and describe children's physical activity behaviours in line with ecological models.
2. Conceiving and successfully implementing a research method which combines multiple tools to provide the information required to understand children's context-specific physical activity.
3. Presenting the results of analyses which show how time spent in specific contexts is associated with MVPA.

### 8.3.1 Implications for theory.

The importance of environmental influences on physical activity is increasingly recognised, and as such use of ecological models that emphasise the environmental and policy contexts of behaviour, while incorporating social and psychological factors, is commonplace (Sallis et al., 2008). Physical activity is not a single act but an entire class of varied behaviours (Sallis & Owen, 1999). Thus when seeking to understand and promote physical activity participation, it is of particular importance to consider how physical activity and its determinants vary by type and context (Bauman et al., 2012). Giles-Corti et al. (2005) have explained the need for ‘increased specificity for ecological models’, whereby behaviour-specific environmental attributes are used to increase capacity to predict and change context-specific behaviours. However, this presents complex questions for researchers. For example, which types and contexts should be investigated and targeted? Moreover, how should physical activity behaviours be categorised and partitioned in the first place?

One approach is to separate physical activity into domains. As described in section 2.5.2, the domains of children’s physical activity are not defined concretely but normally include structured activities such as physical education, after school clubs and organised sport, or unstructured activities such as active commuting, school recess and leisure-time outdoor play (Brockman et al., 2011a; Trost, 2007). The SLOTH (sleep, leisure, occupational, travel and home) model is another which seeks to describe physical activity using domains (Pratt et al., 2004). However, as shown for the domain ‘outdoor play’ in Chapter Three, these labels sometimes apply broad assumptions about even more specific behaviours. This thesis advocates an approach which combines measures of multiple attributes to describe the type and context of physical activity. This work has demonstrated that describing context-specific physical activity in this way can help develop a more representative picture of how, where and with whom it takes place.

However, whilst this approach has been shown to be informative, further questions are posed. For example, which attributes are most influential and in need of further investigation? Perhaps more importantly, how much detail and specificity is required and/or useful? Is there a risk that physical activity could be deconstructed and partitioned to such an extent that the information derived is no longer usable or meaningful? The number and nature of contextual attributes used to describe physical activity must therefore be considered carefully. As was the case for this research, combinations of contextual attributes should be selected and investigated on the basis of exploration of the factors most strongly associated with physical activity, and directions provided by prior research. Qualitative research is particularly useful in this regard due its exploratory nature and ability to provide complex contextual descriptions of emergent or previously unconsidered variables (Creswell, 2003). The implication for theory is that researchers should seek to better understand physical activity behaviours by recording and combining specific contextual attributes. As shown in this thesis, investigating the contributions of different contexts towards total daily MVPA provides detailed information which could inform the kind of interventions that may best promote physical activity. Decisions about which attributes to investigate should be informed by consideration of previous research.

### 8.3.2 Implications for methodology.

The methods used in this thesis have implications for researchers seeking to investigate children's context-specific physical activity. The above approach, which builds a picture of physical activity from different attributes, necessitates a method that can record those attributes. It is also necessary to measure the intensity and duration of physical activity. The research in Chapters Five and Seven demonstrated that it is possible to combine data from different measurement tools to record the physical activity occurring in different contexts. The three tools used were: accelerometry, GPS receivers and self/proxy report diaries. Each of these tools has their own strengths and limitations; however in combination they have provided rich, detailed data about how children obtain their physical activity.

The attributes investigated in this thesis required a method which could record whether individuals were indoors or outdoors. Chapter Six demonstrated that use of the GPS signal-to-noise ratio from the Qstarz receiver (Qstarz BT-Q1000eX; Qstarz International, Taiwan, Republic of China) is an accurate method for recording this contextual attribute in free living individuals. This has implications for those seeking to investigate indoor and outdoor physical activity, or those wishing to remove unreliable indoor data for more complex GPS/GIS data analysis. In addition, the new data presented in Chapter Seven indicate that children are capable of following instructions to charge this GPS receiver nightly to sustain battery life. These findings are encouraging for researchers who wish to record environmental attributes of physical activity over extended periods. Furthermore in Chapter Seven, a very large proportion of valid accelerometer epochs were successfully matched to GPS data, and mean valid days of combined data were comparable to other studies using similar methods (Klinker et al., 2014a). Strategies to encourage accelerometer wear time may also increase GPS wear time if the devices are worn on the same belt.

The studies in Chapters Five and Seven used a similar diary to record contextual attributes of children's leisure-time. In particular, the diary in Chapter Seven was simplified to record only episodes of physical activity occurring in structured contexts, which by their nature are more suited to measurement using subjective reporting than more informal contexts (Kohl et al., 2000). In combination with accelerometer data it was possible to dichotomise leisure-time and estimate the intensity and duration of not only structured leisure-time physical activity, but also unstructured physical activity which can otherwise be difficult to record. Despite limitations when measuring episodes of physical activity that are short, sporadic and unmemorable (Bailey et al., 1995; Baquet et al., 2007), careful choice of the type of attribute to be recorded, and focusing on more regular or memorable events resulted in useful and informative data for combination with more objective measures. The implication for future work is that whilst GPS receivers and accelerometers can provide automated objective data, subjective reporting is still advantageous for recording important contextual attributes of physical activity. Use of time stamps from accelerometer, GPS and diary methods to combine data is a feasible and informative tactic to develop understanding of the context of children's physical activity.

#### *8.3.2.1 Personal reflections on physical activity data collection.*

Chapter 7 used newly collected data from children attending schools in Edinburgh. In comparison to larger studies, the field work was carried out by a single researcher with relatively limited resources. It is therefore constructive to reflect personally on the demands of conducting a cross-sectional observational study in a child population, and the lessons that can be learned for best practice in future work, particularly that of PhD candidates who may face similar barriers.

The equipment available for this study limited the number of participants being observed to 20 at any given time, and this had implications for many aspects of the field work. The most important of these was the fact that data collection in different schools would need to take place sequentially rather than concurrently. This of course extended the duration of the study and imposed a time pressure on the recruitment and observation of sufficient participant numbers for a useful dataset. Time pressures were also introduced by preparation work required for each week of data collection, the need for 'off' weeks between observation periods to retrieve the data, and the time restraints or preferences of the schools themselves. Combined with the overall time limit on PhD degree study, this resulted in a cap on the potential weeks of data collection, and consequently a maximum number of potential participants. These caps served to increase the importance of each observation period, and the cost to the overall sample size when plans did not work as intended.

The above constraints presented important decisions regarding the number of schools invited to be involved in the study. For example, should a greater number of children be recruited at fewer schools, or vice versa? Given the time available, it was decided to lean towards the first option, and limit the number of schools, aiming to recruit a greater number of children at each during multiple weeks of observation. With the benefit of hindsight, this was a high risk strategy. Whilst it was not assumed that each observation period would result in complete data from the maximum of twenty participants per week, the challenges of engaging pupils and staff alike resulted in fewer participants than planned. The resources and level of interest in participation varied substantially between schools. This was surprisingly evident even between state schools, while the level of resource and input from staff at the independent school was even more marked. Understanding the pressures faced by teachers at different schools, and refining the research protocol to suit these demands without introducing sources of bias are key skills when conducting this type of research.

These differences between schools meant that at some schools, complete (i.e. 20/20 participant slots filled) weeks of observation were possible, whereas at others, the number of participants was minimal. In two instances, planned data collection was cancelled by the schools. In these circumstances, almost entire half-terms of available research time was left unexploited. A strategy using a greater number of schools, concentrating on recruiting at least one full week of data collection at each, may have been more successful. Reducing the planned recruitment numbers at each school would have reduced the impact when interest and engagement with the project was low. A greater number of schools may have also enabled greater flexibility in the event that data collection was cancelled, with the possibility of an alternative school stepping in.

Perhaps the most important impact of limited time and resources at some schools was on the number of children invited to take part in the study. In some schools, invitations were understandably limited to one or two classes of approximately twenty children. This would have required an unrealistic uptake of 100% in order to recruit the intended number of participants per school. In contrast, one school offered the opportunity to speak with the entire S1 year group, and consequently it was possible to complete multiple weeks of data collection even though uptake was approximately 30%.

The ease of generating interest in the study seemed to vary with the interest of the staff and the time available to introduce the project. Inviting children to take part in the study as large group during an assembly appeared to generate enthusiasm for the project in a way that working in smaller groups during class time did not. Time available in class was often restricted, and as a result the introduction to the study felt rushed. This meant that it was difficult to convey the key points of the study, including the need to return informed consent forms necessary to take part. It was disappointing to observe that at one school, many children who were interested in taking part in the study could not do so because they had either forgotten to have the consent form signed, or had left signed copies at home. Other observations which may help guide future recruitment strategies include the reluctance of children to give up their lunch or morning break periods and the importance of peer influences. On a few occasions, a domino effect seemed to take place once one participant withdrew from the study, resulting in friends also choosing to withdraw. It is difficult to provide recommendations on how to deal with these phenomena, and this could form the basis of future research.

The interest and passion of teachers assigned to help coordinate the project was also important to drive recruitment. In particular, some teachers appeared to be motivated by a sense of competition between schools, shown by their interest in which other schools had taken part and how well the pupils had conducted themselves in the study. In some cases, there appeared to be a sense of pride in wanting to ensure they contributed the largest number of participants and that these pupils provided the fullest datasets for the research. Advising teachers of the participation of other schools, and when their data collection was to take place also helped to reinforce the time pressures of the research project.

Once children and parents had agreed to take part, the data collection process was then surprisingly straightforward. The vast majority of children were adept at fitting the device belt and understanding the requirement to charge the GPS receiver. Overall participants adhered well to the study protocol. Across all observation weeks, only one device was not returned, the remainder were returned undamaged and fully functioning. This is not to say that all participants returned the devices on time, in some instances some degree of chasing was involved, and on these occasions the involvement of the teacher and school secretary was required.

Aspects of the preparation for data collection may have contributed to these successes. Equipment was marked with a number and delivered to children in numbered packs. This seemed to work well in terms of keeping all the research materials together and avoided mix-ups between participants. All equipment was fully charged, switched on and ready for wear on the first day of data collection. This lack of tampering and fiddling with devices on the day appeared to reinforce the idea to the children that all they had to do was wear the device for as much of the week as possible. Using the same place and time for commencing and ending each observation period also seemed to help children remember where and when the study was taking place, especially when multiple weeks of data collection took place at the same school. Finally, whilst the participants took to the task of fitting and wearing the devices with ease, offering them the opportunity to ask questions about the protocol was beneficial. In most instances, children raised questions such as 'is it waterproof?' or 'do I wear it in bed?' Whilst most answers had been previously explained, the opportunity to question the methods used helped reinforce what was required, as well as allowing children to demonstrate their own critical thinking, perhaps enhancing their engagement with the research.

Based on these experiences, below are listed eight recommendations for researchers, particularly those conducting field work with relatively limited resources:

- When equipment and manpower are relatively limited and data collection must take place sequentially at different sites, it is important to be realistic about the target sample size. Consider the need for preparation time, requirement for 'off weeks', the lack of availability to use first and last weeks or days of term; these factors will impact the total number of observation periods and limit the potential number of participants. The maximum sample size will be the product of the number of pieces of available equipment and the number of potential observation weeks (or other observation period durations).
- Limit the reliance on individual schools and the impact of data collection snags or difficulties by recruiting the maximum number of schools possible and aiming for at least one observation period from each, at least in the first

instance. Random or stratified random sampling of schools can be used when there are more schools than available observation periods.

- Understand the schools, their pupils and the pressures on teachers. Conduct research on the schools and the local area from which children are drawn. These factors may necessitate minor alterations to the recruitment protocol.
- If possible, request to speak to the entire year group(s) of interest rather than individual classes. This can help create generate excitement around the study, maximises the potential number of participants and can lead to more complete use of available equipment even if the overall recruitment rate is low.
- Allow children adequate time to return informed consent forms. Set clear deadlines, and if possible, conduct this part of the recruitment process some time before the observation period is due to take place. Direct letters to parents can be useful, but the availability of this method is dependent upon existing communication policies within different schools.
- Tap into the enthusiasm of teachers and their sense of competition with other schools.
- Use clearly numbered equipment and packs to help children understand which equipment is for their use. Use the same times and places to conduct data collections sessions and if possible avoid use of lunch of break periods. The time immediately before schools worked particularly well at one site.
- Finally, before entering into this type of research, carefully consider whether the collection of new data is necessary or whether the research questions be answered using existing data. There may be possible collaborations or expertise which may help enhance the work. In some instances there may be opportunities to utilise much larger data sets which could not be realistically collected by one individual. However, because data have already been collected, this may result in some concessions in terms of the exact nature of the data used for analysis.

### 8.3.3 Implications for physical activity behaviour change.

This thesis contributes to the emerging evidence about the indoor and outdoor contexts of children's leisure-time physical activity. The cross-sectional data reported in Chapters Five and Seven, plus the review in Chapter Four, provide important but preliminary information about how children's leisure-time may be best modified to change physical activity behaviour.

The findings of Chapters Five and Seven suggest that children obtain their physical activity in multiple contexts and that no single context can fulfil the requirement for 60 minutes of MVPA per day. This is consistent with guidance from GAPA (2011), which advocates whole-of-school approaches that provide various opportunities for structured and unstructured physical activity throughout the day. As described in section 2.5.1, the majority of children's physical activity occurs outside of school-time, but to date most interventions have been school-based and have had limited success affecting leisure-time physical activity (Cale & Harris, 2006; Dobbins et al., 2013). This thesis emphasises the potential of leisure-time to supplement or even exceed physical activity obtained during school-time. Further work that measures the effectiveness of interventions tailored to increase physical activity outside of school as components of whole-of-school programs is therefore required.

Interventions to promote physical activity specifically during after school leisure-time have been ineffective (Atkin et al., 2011). This thesis contributes new data which can perhaps guide future efforts towards promising intervention targets. Data presented in Chapter Seven suggest that structured outdoor contexts have the potential to contribute large volumes of MVPA. However, it was also found that even amongst a relatively affluent and active sample of children who are reported to undertake more of this type of activity (Maher & Olds, 2009; Payne et al., 2013), participation in structured physical activity was very limited. Whilst this would appear to offer great scope for improvement, previous attempts to encourage participation through structured after school clubs have been unsuccessful due to the pre-existence of this type of opportunity, many of which are poorly attended (Jago & Baranowski, 2004). It may be possible to exploit pre-existing networks of after school clubs, however it is suggested that it will be necessary to provide very attractive opportunities and facilitate transport to and from activity locations (Jago & Baranowski, 2004). Structured physical activity introduces other barriers such as cost, and may not suit many children's preferences (Allender et al., 2006). Structured sport and exercise may also be reminiscent of physical education for many inactive or overweight children, and being forced to engage in vigorous physical activity in the presence of peers may lead to stigmatization or reactance, resulting in adverse effects on physical activity levels (Dobbins et al., 2013). Thus despite the potentially high yield of MVPA demonstrated in Chapter Seven, it is questionable whether promoting structured opportunities should be the focus of future interventions because: they are poorly attended, are relatively costly, and may not engage those children most in need of intervention. Alternative strategies that overcome these barriers may be more effective.

In support of existing literature, it was shown in both Chapter Five and Chapter Seven that a large proportion children's leisure-time is spent indoors. It followed that in both studies, indoor leisure-time made a large contribution to daily MVPA. This indoor time, which was shown to be mostly unstructured and spent with parents, could be an important target for intervention. Previous reviews report strong evidence of the effectiveness of multi-component school-based interventions which included family involvement (Salmon, Booth, Phongsavan, Murphy, & Timperio, 2007; van Sluijs et al., 2007). Evidence presented here suggests children spend much of their time indoors with parents, and this reflects the need to include parents in promotion strategies and consider alterations to the home environment.

Alternatively, it may be more beneficial to reduce time indoors altogether in favour of time outdoors. Chapters Five and Seven are both consistent with literature showing that time outdoors is positively associated with physical activity (Cleland et al., 2008; Cleland et al., 2010; Cooper et al., 2010; Stone & Faulkner, 2014; Wen et al., 2009). Promoting unstructured outdoor physical activity, which children engage in at their own discretion and with greater choice over their behaviour, may be a more suitable strategy to engage more inactive children. A review of interventions targeting the after school period has suggested that single-behaviour strategies may be most successful

(Atkin et al., 2011). This thesis emphasises the crucial role of unstructured outdoor leisure-time as a component of future interventions. Promoting unstructured outdoor leisure-time rather than physical activity per se, or pushing children into structured sport and exercise, may be a strategy whereby physical activity is increased 'by stealth' (Brockman & Fox, 2011), with children walking and travelling actively, meeting other children, playing and exploring their local environment. Increasing time outdoors would also likely have a secondary benefit of reducing sedentary behaviours associated with television and computer game usage (Stone & Faulkner, 2014).

Realistically this thesis can only offer tentative suggestions for how this might be achieved. Chapter Five suggests that time outdoors with other children is particularly conducive to MVPA. This echoes research from the review in Chapter Three, which revealed having other children to play with and independent mobility are consistently associated with outdoor play. Parental rules and safety fears resulting from environmental barriers were also important. The influences of parental rules and restrictions have been shown to be particularly important during the after school period, children being more active they were allowed to play outside anywhere in the neighbourhood and less restricted in their movement to friends' homes (McMinn, Griffin, Jones, & van Sluijs, 2013). Encouraging unstructured outdoor time may therefore be achieved by helping children form social groups and giving parents the confidence to permit greater independent mobility by creating safer, more cohesive neighbourhoods. These findings point to a requirement for multi-component interventions including school, community and parental involvement (Salmon et al., 2007; van Sluijs et al., 2007). Attempts to use multi-level interventions to 're-establish a social fabric of friendship, support and mutual trust' and combat 'hyper-protective parental attitudes' have been somewhat successful (Prezza, Alparone, Renzi, & Pietrobono, 2010), and manipulating the physical and social environment to be child-friendly with this kind of effort could result in a positive cycle of mobility licenses and use of those environments (Kytta, 2004).

To summarise, the implications of this thesis for physical activity behaviour change are:

- Interventions should continue to target multiple contexts of physical activity behaviour as part of whole-of-school programs, and in particular interventions which target leisure-time physical activity should be pursued.
- It may be more beneficial to focus on unstructured physical activities such as play and active travel rather than structured opportunities such as after school clubs and sport.
- Parental and home influences should be targeted to maximise physical activity accrued during the considerable time children spend indoors as well as promote time outdoors.
- Interventions that target increased time outdoors rather than physical activity per se may also be beneficial and could increase physical activity ‘by stealth’.
- Parental, community and school involvement should be considered as components of interventions to modify factors related to unstructured outdoor time such as: parental safety concerns, social interaction and independent mobility.

## 8.4 Limitations

Use of accelerometry to measure children’s physical activity has acknowledged strengths and weaknesses as described in section 2.3.3.3. In common with other studies that have used accelerometry, this work has likely underestimated the contributions of certain types of physical activity such as cycling and swimming. The studies in Chapters Five and Seven used different accelerometer models, different axis settings (uni-axial vs tri-axial) and different cut-points to estimate MVPA. Whilst the aim was not to make direct comparisons between these studies, the variation in the methods used exemplifies the wider problem in the field of physical activity research. The key strength of this research is the combination of three sources of data to provide a rich description of the type and context of children’s physical activity. If, as is necessary, further work is conducted to describe different contextual attributes and provide more details about how children obtain their physical activity, then appraising data from different studies may become more difficult due to variation in the methods used. Methods using GPS receivers are advancing to provide more and more informative data about the geographic location of physical activity. For example Southward et al. (2012) measured physical activity occurring specifically on the walking route to and from school. However, these methods and definitions could become at least as diverse as accelerometer or self-report techniques. This may further complicate the integration and interpretation of the body of literature as a whole to make recommendations about how best to intervene. On the other hand, multiple lines of evidence converging on the same finding provide strong evidence, for example the relationship between time outdoors and MVPA during leisure-time has been demonstrated using diverse methods. The implication is that researchers should work together to standardise how contextual attributes of physical activity are derived and defined, and continue to refine best practice guidelines for collecting and processing GPS data (Kerr et al., 2011).

This thesis described cross-sectional data in Chapters Five and Seven. This type of analysis means that it is not possible to determine the direction of the relationships observed. The findings have highlighted the contexts in which children are more active and less active. However, because the direction of causality cannot be inferred, it is impossible to say whether time spent in those contexts caused variation in physical activity, or whether being a more or less active child resulted in variation in time spent in those contexts. This means that the findings of this thesis are preliminary, and based on the evidence presented it cannot be assumed that uptake of time spent in the contexts identified will result in greater physical activity. Furthermore, it is not possible to say how context exerts influence on physical activity intensity, for example whether these environmental attributes are mediated by cognition or act directly on behaviour (Kremers et al., 2006). However, the results are indicative of the contexts which can help children meet MVPA guidelines, and of potential barriers that inactive children may face (e.g. being stuck indoors alone, no children to play with).

The current UK Governments recommend 60 minutes MVPA per day for children (Department of Health, 2011). The research questions of this thesis therefore focused on MVPA, as this is the intensity of physical activity required to stimulate the cardiorespiratory, musculoskeletal and metabolic systems (Department of Health, 2011). Consequently, in Chapters Five and Seven, each epoch of accelerometer data was dichotomised as either MVPA, or not MVPA, according to calibrated cut-points. The findings of this thesis provide information about the contexts in which MVPA occurs, the implication being that interventions that encourage time spent in those contexts could help children reach 60 minutes of MVPA per day. However, it could be argued that in trying to understand the pattern of children's activity, this research is limited by considering only MVPA, and not sedentary behaviours or light physical activity. Encouraging very inactive children to utilise the same contexts in which their more active counterparts accrue MVPA may not be effective, because those children may simply continue to be inactive, albeit in a different place, time or social setting. Inactive children may need or desire access to very different physical activity contexts. The dose-response for physical activity indicates that the greatest benefit of interventions for population health comes from moving very inactive individuals to at least some activity (Department of Health, 2011). Very inactive children record little or no MVPA, by dichotomising their accelerometer output using accelerometer count thresholds, valuable continuous data about how their physical activity varies by context may have been lost (Streiner, 2002). A more subtle approach (for example using accelerometer counts) may be required to understand the specific contexts where very inactive children are most active. Understanding the contexts where sedentary behaviours occur may also be necessary, however sedentary behaviour is not just the absence of physical activity but a separate behaviour in its own right (Tremblay et al., 2010), and as such this analysis was outwith the scope of this thesis.

The current project focused on children at the transition from primary to secondary school as it is at approximately this age that independence from adults begins to develop (Jago et al., 2009; O'Brien et al., 2000). The cross-sectional nature of the work presented in Chapters Five and Seven also denies tracking of changes in the types and contexts of physical activity children engage in as they progress into adolescence. Whilst promoting physical activity amongst inactive individuals is a primary concern, it is also recognised that participation decreases as children move into adolescence (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). Understanding how the profile of physical activity changes with age may provide vital information about how to arrest this decline, and this was not possible using cross-sectional analyses or the limited age range of the children included. The experiences and physical activity profiles of children outside these age ranges may be very different. In particular it is known that independent mobility increases with age and this greater license afforded to older teenagers may have a profound relationship with how they spend their leisure-time. Ideally, both the work in Chapter Five and Chapter Seven would have tracked context-specific physical activity across the transition from primary to secondary school, or better, across an even greater number of years. Unfortunately this was not feasible within the timescales of the project, and reproducing this type of work over many years may also be burdensome to participants and expensive to conduct. The work is also limited by relatively small samples size, particularly in Chapter Seven. This restricted stratification by demographic characteristics, particularly sex and SES which have been shown to be associated with the profile of children's physical activity (Payne et al., 2013).

A key concern for this research and for similar work going forward is the use of single days of measurement to describe context-specific physical activity. Researchers are most often interested in summarising daily physical activity, because days organise human experiences (Baranowski, Masse, Ragan, & Welk, 2008). Habitual physical activity varies from day to day, so to record a reliable estimate the mean from multiple days of measurement is used. Investigators typically wish to minimise participant burden, and provide balance between reliability and excessive reduction in sample size which can lead to bias. As discussed in section 7.3.3.2, the minimum number of days required to provide a reliable estimate of the pattern of overall physical activity is contentious. However, the matter is more complicated when investigating specific types and contexts of physical activity behaviour. The number of days of measurement is dependent on the variability that exists within the data; behaviours with low intra-individual and high inter-individual variability are more reliable and require fewer days of measurement, while more days of observation are required for behaviours with high intra-individual and low inter-individual variability (Baranowski et al., 2008). It is likely that the reliability of measures of physical activity is context-specific. As stated by Klinker et al. (2014b), to date no study has investigated the minimum number of days required to obtain reliable estimates of children's context-specific physical activity patterns. In terms of this research, it is difficult to say what effect the use of one day of measurement for some individuals may have had on the relationships reported, however it is suggested that in particular estimates of MVPA occurring in structured contexts should be treated with caution. One solution has been to adjust for number of valid days each individual recorded (Klinker et al., 2014a), however this assumes that even those children with fullest datasets will provide reliable estimates of the contributions of behaviours with high intra- and low inter-individual variability. Vastly extended periods of observation may be required to fully assess the contributions of some types and contexts of physical activity.

## 8.5 Recommendations for Future Research

In light of the findings of this thesis and the preceding discussion, this section suggests avenues of research for further work. This thesis investigated influential contextual attributes based on a review of quantitative and qualitative evidence. It is necessary to record how physical activity levels vary according to other important contextual attributes. Deeper understanding of the geographic locations children use during their leisure-time is required, and in particular, this thesis suggests that informal spaces used for unstructured outdoor physical activity are vital. There is also a need to move beyond which contexts are most supportive of physical activity to when, how and for whom (Kremers et al., 2006). One physical-environmental feature which emerged from the review in Chapter Three is the supportiveness of cul-de-sac neighbourhoods for unstructured outdoor physical activity. Further investigation of how this street design relates to independent mobility and physical activity is suggested. The use of GPS receivers in combination with accelerometers is already proving to be informative in this field of research (Coombes, van Sluijs, & Jones, 2013; Klinker et al., 2014a; Klinker et al., 2014b; Rainham et al., 2012). However, as shown here, additional layers of contextual information from self- or proxy-report dairies can help provide an even richer description of how children spend their time. Furthermore, with technology such as SenseCam (Doherty et al., 2013) and Ecological Momentary Assessment using mobile phones (Dunton et al., 2011), opportunities to develop combined datasets are advancing. Moore’s law suggests that computing power doubles approximately every two years, and this will likely have huge implications for health sciences and physical activity research (Heath, 2014, October 14). At present the aforementioned technologies represent the cutting edge, however it is possible measurement capabilities could change profoundly in less than a decade. The increasing power of personal computers, smartphones and gaming systems may also have great impact on physical activity and sedentary behaviours themselves. Researchers will need to keep pace with these advances and ensure that measures are reliable and valid, but also consider the ethics of the increasingly personal insights afforded, especially in child populations. Whilst quantitative measures will evolve and prove invaluable to more fully describe physical activity, the review in Chapter Three demonstrated the value of qualitative studies when attempting to explain children's leisure-time experiences. Additional mixed methods research combining GPS and accelerometer data with focus groups and interviews (Moore et al., 2014), will also guide context and subgroup specific interventions.

Recording the context and profile of children's physical activity is useful as it provides information about what kinds of physical activity behaviours should be targeted. However, further research is required to reveal why some children encounter certain contexts more than others, and why the physical activity profile of children varies. Consistent with the behavioural epidemiological framework, this work should occur in two stages (Sallis et al., 2000a). Firstly, subgroup analyses should be conducted to discover whether the profile of physical activity varies according to demographic factors such as age, sex and SES. This work would help identify specific imbalances in the physical activity profiles of different groups, for example, children of lower SES may be more restricted in their access to structured sport and exercise. Secondly, determinants specific to subgroups and their particular profile of physical activity should be investigated as potential mechanisms for behaviour change. For example, it may be that younger children and girls have limited opportunities for unstructured outdoor physical activity. Better understanding the potential causes of this imbalance, such as parental safety fears, could help inform an intervention strategy. Community and parental involvement may be key to the success of intervention efforts (Salmon et al., 2007; van Sluijs et al., 2007), so it follows that these groups should also be the focus of research to understand how community cohesion and parental decision-making influence the source of children's physical activity. A key improvement on the work of this thesis and of most work in the field would be adoption of a longitudinal study design to track changes in the contributions of different physical activity contexts and relationships with determinants over time. In particular, it may be possible to observe which contexts contribute to the decline in overall physical activity as children advance through their teenage years (Dumith, Gigante, Domingues, & Kohl, 2011).

To aid the aforementioned research, some methodological knowledge gaps must be addressed. Of immediate need of attention is the question of what is required to obtain reliable estimates of context-specific measures of physical activity. At present, investigators are taking guidance from accelerometer studies, but decision rules about non-wear time and the minimum observation periods may not hold when investigating physical activity of specific types and in specific contexts. These questions become more complex when contexts are combined to form an overall physical activity profile; it is therefore necessary to consider how contextual variables with different levels of intra- and inter-individual variability should be integrated. In addition, as the numerous contextual attributes of physical activity are investigated and explored, a framework to guide definitions of how, where, when, and with whom activity occurs may be necessary. Such a framework could take inspiration from models of determinants such as the ecological model of health behaviour (Sallis et al., 2008), by separating contextual attributes into different levels of influence.

Finally, although this research has focused on associations between contextual attributes and physical activity, this is only one piece of the jigsaw. This research adopted an ecological approach for understanding and influencing behaviours, a key principle of which is that influences interact between levels, and that healthy behaviours such as physical activity are maximised when environments and policies are supportive, when social norms and support are strong, and when individuals are educated and motivated (Sallis et al., 2008). Further work is required to determine how influences at other levels of the ecological model may be best manipulated in synergy with changes to the contexts children use and have access to, for example developing educational and motivational strategies or policy initiatives that enable children to make use of the outdoor environment for physical activity during leisure-time.

# References

Aarts, M. J., de Vries, S. I., van Oers, H. A., & Schuit, A. J. (2012). Outdoor play among children in relation to neighborhood characteristics: a cross-sectional neighborhood observation study. *Int J Behav Nutr Phys Act, 9*, 98. doi: 10.1186/1479-5868-9-98

Aarts, M. J., Wendel-Vos, W., van Oers, H. A., van de Goor, I. A., & Schuit, A. J. (2010). Environmental determinants of outdoor play in children: a large-scale cross-sectional study. *Am J Prev Med, 39*(3), 212-219. doi: 10.1016/j.amepre.2010.05.008

Active Healthy Kids Canada. (2012). Is Active Play Extinct? 2012 Active Healthy Kids Canada Report Card on Physical Activity for Children and Youth. Retrieved from Active Healthy Kids Canada website: http://www.activehealthykids.ca

Active Healthy Kids Scotland. (2013). The 2013 Active Healthy Kids Scotland Report Card. Retrieved from Active Healthy Kids Scotland website: http://www.activehealthykidsscotland.co.uk

Adamo, K. B., Prince, S. A., Tricco, A. C., Connor-Gorber, S., & Tremblay, M. (2009). A comparison of indirect versus direct measures for assessing physical activity in the pediatric population: a systematic review. *Pediatr Obes, 4*(1), 2-27. doi: 10.1080/17477160802315010

Ainsworth, B. E., Caspersen, C. J., Matthews, C. E., Mâsse, L. C., Baranowski, T., & Zhu, W. (2012). Recommendations to improve the accuracy of estimates of physical activity derived from self report. *J Phys Act Health, 9*(0 1), S76-S84.

Ainsworth, B. E., Haskell, W. L., Herrmann, S. D., Meckes, N., Bassett, D. R., Jr., Tudor-Locke, C., . . . Leon, A. S. (2011). 2011 compendium of physical activities: a second update of codes and MET values. *Med Sci Sports Exerc, 43*(8), 1575-1581. doi: 10.1249/MSS.0b013e31821ece12

Ainsworth, B. E., Haskell, W. L., Leon, A. S., Jacobs, D. R., Jr., Montoye, H. J., Sallis, J. F., & Paffenbarger, R. S., Jr. (1993). Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc, 25*(1), 71-80.

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., . . . Leon, A. S. (2000). Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc, 32*(9 Suppl), S498-504.

Ajzen, I. (1985). From Intentions to Actions: A Theory of Planned Behavior. In J. Kuhl & J. Beckmann (Eds.), *Action Control* (pp. 11-39): Springer Berlin Heidelberg.

Allender, S., Cowburn, G., & Foster, C. (2006). Understanding participation in sport and physical activity among children and adults: a review of qualitative studies. *Health Educ Res, 21*(6), 826-835. doi: 10.1093/her/cyl063

Allor, K. M., & Pivarnik, J. M. (2001). Stability and convergent validity of three physical activity assessments. *Med Sci Sports Exerc, 33*(4), 671-676.

Anderson, S. E., Economos, C. D., & Must, A. (2008). Active play and screen time in US children aged 4 to 11 years in relation to sociodemographic and weight status characteristics: a nationally representative cross-sectional analysis. *BMC Publ Health, 8*, 366. doi: 10.1186/1471-2458-8-366

Armstrong, N. (1998). Young people's physical activity patterns as assessed by heart rate monitoring. *J Sports Sci, 16 Suppl*, S9-16. doi: 10.1080/026404198366632

Armstrong, N., Balding, J., Gentle, P., & Kirby, B. (1990). Patterns of physical activity among 11 to 16 year old British children. *BMJ, 301*(6745), 203-205.

Armstrong, N., & Welsman, J. R. (2006). The physical activity patterns of European youth with reference to methods of assessment. *Sports Med, 36*(12), 1067-1086.

Atkin, A. J., Gorely, T., Biddle, S. J., Cavill, N., & Foster, C. (2011). Interventions to promote physical activity in young people conducted in the hours immediately after school: a systematic review. *Int J Behav Med, 18*(3), 176-187. doi: 10.1007/s12529-010-9111-z

Atkin, A. J., Gorely, T., Biddle, S. J. H., Marshall, S. J., & Cameron, N. (2008). Critical hours: Physical activity and sedentary behavior of adolescents after school. *Pediatr Exerc Sci, 20*(4), 446-456.

Aznar, S., Naylor, P. J., Silva, P., Perez, M., Angulo, T., Laguna, M., . . . Lopez-Chicharro, J. (2011). Patterns of physical activity in Spanish children: a descriptive pilot study. *Child Care Health Dev, 37*(3), 322-328. doi: 10.1111/j.1365-2214.2010.01175.x

Bailey, R. C., Olson, J., Pepper, S. L., Porszasz, J., Barstow, T. J., & Cooper, D. M. (1995). The level and tempo of childrens physical activities - an observational study. *Med Sci Sports Exerc, 27*(7), 1033-1041.

Baquet, G., Stratton, G., Van Praagh, E., & Berthoin, S. (2007). Improving physical activity assessment in prepubertal children with high-frequency accelerometry monitoring: a methodological issue. *Prev Med, 44*(2), 143-147.

Baranowski, T., Dworkin, R. J., Cieslik, C. J., Hooks, P., Clearman, D. R., Ray, L., . . . Nader, P. R. (1984). Reliability and validity of self report of aerobic activity: family health project. *Res Q Exerc Sport, 55*(4), 309-317. doi: 10.1080/02701367.1984.10608408

Baranowski, T., Masse, L. C., Ragan, B., & Welk, G. (2008). How many days was that? We're still not sure, but we're asking the question better! *Med Sci Sports Exerc, 40*(7 Suppl), S544-549. doi: 10.1249/MSS.0b013e31817c6651

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J., & Martin, B. W. (2012). Correlates of physical activity: why are some people physically active and others not? *Lancet, 380*(9838), 258-271. doi: 10.1016/s0140-6736(12)60735-1

Bauman, A. E., Sallis, J. F., Dzewaltowski, D. A., & Owen, N. (2002). Toward a better understanding of the influences on physical activity: the role of determinants, correlates, causal variables, mediators, moderators, and confounders. *Am J Prev Med, 23*(2 Suppl), 5-14.

Becker, M. H., & Maiman, L. A. (1975). Sociobehavioral determinants of compliance with health and medical care recommendations. *Med Care, 13*(1), 10-24.

Beets, M. W., Banda, J. A., Erwin, H. E., & Beighle, A. (2011). A pictorial view of the physical activity socialization of young adolescents outside of school. *Res Q Exerc Sport, 82*(4), 769-778.

Biddle, S. J., Marshall, S. J., Gorely, T., & Cameron, N. (2009). Temporal and environmental patterns of sedentary and active behaviors during adolescents' leisure time. *Int J Behav Med, 16*(3), 278-286. doi: 10.1007/s12529-008-9028-y

Blaes, A., Baquet, G., Fabre, C., Van Praagh, E., & Berthoin, S. (2011). Is there any relationship between physical activity level and patterns, and physical performance in children? *Int J Behav Nutr Phys Act, 8*, 122. doi: 10.1186/1479-5868-8-122

Bratteby, L. E., Sandhagen, B., Fan, H., & Samuelson, G. (1997). A 7-day activity diary for assessment of daily energy expenditure validated by the doubly labelled water method in adolescents. *Eur J Clin Nutr, 51*(9), 585-591.

Bringolf-Isler, B., Grize, L., Mader, U., Ruch, N., Sennhauser, F. H., & Braun-Fahrlander, C. (2009). Assessment of intensity, prevalence and duration of everyday activities in Swiss school children: a cross-sectional analysis of accelerometer and diary data. *Int J Behav Nutr Phys Act, 6*, 50. doi: 10.1186/1479-5868-6-50

Bringolf-Isler, B., Grize, L., Mader, U., Ruch, N., Sennhauser, F. H., Braun-Fahrlander, C., & team, S. (2010). Built environment, parents' perception, and children's vigorous outdoor play. *Prev Med, 50*(5-6), 251-256.

British Heart Foundation National Centre for Physical Activity and Health. (2012). Evidence Briefing: Sedentary Behaviour. Retrieved from British Heart Foundation National Centre for Physical Activity and Health website: http://www.bhfactive.org.uk

Brockman, R., & Fox, K. R. (2011). Physical activity by stealth? The potential health benefits of a workplace transport plan. *Public Health, 125*(4), 210-216. doi: 10.1016/j.puhe.2011.01.005

Brockman, R., Fox, K. R., & Jago, R. (2011a). What is the meaning and nature of active play for today's children in the UK? *Int J Behav Nutr Phys Act, 8*, 15. doi: 10.1186/1479-5868-8-15

Brockman, R., Jago, R., & Fox, K. R. (2010). The contribution of active play to the physical activity of primary school children. *Prev Med, 51*(2), 144-147.

Brockman, R., Jago, R., & Fox, K. R. (2011b). Children's active play: self-reported motivators, barriers and facilitators. *BMC Publ Health, 11*, 461. doi: 10.1186/1471-2458-11-461

Brockman, R., Jago, R., Fox, K. R., Thompson, J. L., Cartwright, K., & Page, A. S. (2009). "Get off the sofa and go and play": family and socioeconomic influences on the physical activity of 10-11 year old children. *BMC Publ Health, 9*, 253. doi: 10.1186/1471-2458-9-253

Burdette, H., & Whitaker, R. (2005a). Resurrecting free play in young children. *Arch Pediatr Adolesc Med, 159*(1), 46-50.

Burdette, H. L., & Whitaker, R. C. (2005b). Resurrecting free play in young children. *Arch Pediatr Adolesc Med, 159*(1), 46-50.

Cain, K. L., Sallis, J. F., Conway, T. L., Van Dyck, D., & Calhoon, L. (2013). Using accelerometers in youth physical activity studies: a review of methods. *J Phys Act Health, 10*(3), 437-450.

Cale, L., & Harris, J. (2006). Interventions to promote young people’s physical activity: Issues, implications and recommendations for practice. *Health Educ J, 65*(4), 320-337.

Carver, A., Timperio, A., & Crawford, D. (2008). Playing it safe: the influence of neighbourhood safety on children's physical activity - a review. *Health Place, 14*(2), 217-227. doi: 10.1016/j.healthplace.2007.06.004

Carver, A., Timperio, A., Hesketh, K., & Crawford, D. (2010). Are children and adolescents less active if parents restrict their physical activity and active transport due to perceived risk? *Soc Sci Med, 70*(11), 1799-1805.

Carver, A., Timperio, A., Hesketh, K., & Crawford, D. (2012). How does perceived risk mediate associations between perceived safety and parental restriction of adolescents' physical activity in their neighborhood? *Int J Behav Nutr Phys Act, 9*(1), 57. doi: 10.1186/1479-5868-9-57

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep, 100*(2), 126-131.

Centers for Disease Control and Prevention. (2003). Physical activity levels among children aged 9-13 years-United States, 2002. *Morb Mortal Wkly Rep, 52*(33), 785-788.

Cho, G.-H., Rodriguez, D. A., & Evenson, K. R. (2011). Identifying walking trips using GPS data. *Med Sci Sports Exerc, 43*(2), 365-372. doi: 10.1249/MSS.0b013e3181ebec3c

Choi, L., Liu, Z., Matthews, C. E., & Buchowski, M. S. (2011). Validation of accelerometer wear and nonwear time classification algorithm. *Med Sci Sports Exerc, 43*(2), 357-364. doi: 10.1249/MSS.0b013e3181ed61a3

Cleland, V., Crawford, D., Baur, L. A., Hume, C., Timperio, A., & Salmon, J. (2008). A prospective examination of children's time spent outdoors, objectively measured physical activity and overweight. *Int J Obes, 32*(11), 1685-1693.

Cleland, V., Timperio, A., Salmon, J., Hume, C., Baur, L. A., & Crawford, D. (2010). Predictors of time spent outdoors among children: 5-year longitudinal findings. *J Epidemiol Community Health, 64*(5), 400-406. doi: 10.1136/jech.2009.087460

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). New York: Academic Press.

Cole, T. J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ, 320*(7244), 1240-1243.

Colley, R., Connor Gorber, S., & Tremblay, M. S. (2010). Quality control and data reduction procedures for accelerometry-derived measures of physical activity. *Health Rep, 21*(1), 63-69.

Collins, P., Al-Nakeeb, Y., Nevill, A., & Lyons, M. (2012). The impact of the built environment on young people's physical activity patterns: a suburban-rural comparison using GPS. *Int J Environ Res Publ Health, 9*(9), 3030-3050. doi: 10.3390/ijerph9093030

Coombes, E., van Sluijs, E., & Jones, A. (2013). Is environmental setting associated with the intensity and duration of children's physical activity? Findings from the SPEEDY GPS study. *Health Place, 20*, 62-65. doi: 10.1016/j.healthplace.2012.11.008

Cooper, A. R., Andersen, L. B., Wedderkopp, N., Page, A. S., & Froberg, K. (2005). Physical activity levels of children who walk, cycle, or are driven to school. *Am J Prev Med, 29*(3), 179-184. doi: 10.1016/j.ampre.2005.05.009

Cooper, A. R., & Page, A. S. (2010). Measurement of Children's Physical Activity in the Environment: UK Perspective. In A. A. Lake, T. G. Townshend & S. Alvanides (Eds.), *Obesogenic Environments: Complexities, Perceptions and Objective Measurement*. Oxford, UK: Wiley-Blackwell.

Cooper, A. R., Page, A. S., Wheeler, B. W., Hillsdon, M., Griew, P., & Jago, R. (2010). Patterns of GPS measured time outdoors after school and objective physical activity in English children: the PEACH project. *Int J Behav Nutr Phys Act, 7*, 31. doi: 10.1186/1479-5868-7-31

Cooper, A. R., Wedderkopp, N., Wang, H., Andersen, L. B., Froberg, K., & Page, A. S. (2006). Active travel to school and cardiovascular fitness in Danish children and adolescents. *Med Sci Sports Exerc, 38*(10), 1724-1731.

Corder, K., Ekelund, U., Steele, R. M., Wareham, N. J., & Brage, S. (2008). Assessment of physical activity in youth. *J Appl Physiol, 105*(3), 977-987. doi: 10.1152/japplphysiol.00094.2008

Corder, K., van Sluijs, E. M., Wright, A., Whincup, P., Wareham, N. J., & Ekelund, U. (2009). Is it possible to assess free-living physical activity and energy expenditure in young people by self-report? *Am J Clin Nutr, 89*(3), 862-870. doi: 10.3945/ajcn.2008.26739

Cox, M., Schofield, G., Greasley, N., & Kolt, G. S. (2006). Pedometer steps in primary school-aged children: a comparison of school-based and out-of-school activity. *J Sci Med Sport, 9*(1-2), 91-97. doi: 10.1016/j.jsams.2005.11.003

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ, 337*, a1655. doi: 10.1136/bmj.a1655

Creswell, J. W. (2003). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. Thousand Oaks, CA: SAGE Publications.

Currie, C., Levin, K., Kirby, J., Currie, D., van der Sluijs , W., & Inchley, J. (2011). Health Behaviour in School-aged Children: World Health Organization Collaborative Cross-National Study (HBSC): findings from the 2010 HBSC survey in Scotland: Child and Adolescent Health Research Unit, The University of Edinburgh.

Currie, C., Zanotti, C., Morgan, A., Currie, D., de Looze, M., Roberts, C., . . . Barnekow, V. (2012). Social determinants of health and well-being among young people. Health Behaviour in School-aged Children (HBSC) study: international report from the 2009/2010 survey. Copenhagen: WHO Regional Office for Europe.

Curtis, A. D., Hinckson, E. A., & Water, T. C. (2012). Physical activity is not play: perceptions of children and parents from deprived areas. *New Zeal Med J, 125*(1365), 38-47.

Davison, K. K., & Lawson, C. T. (2006). Do attributes in the physical environment influence children's physical activity? A review of the literature. *Int J Behav Nutr Phys Act, 3*, 19. doi: 10.1186/1479-5868-3-19

Department for Transport. (2013). Table NTS9908 Trips to and from school by main mode—region and area type: Great Britain, 2011/12 [database online]. Retrieved from UK Government website: https://www.gov.uk/government/statistical-data-sets/nts99-travel-by-regionand-area-type-of-residence

Department of Health. (2004). *At least five a week: Evidence on the impact of physical activity and its relationship to health*. London: Department of Health.

Department of Health. (2011). *Start active, stay active: a report on physical activity from the four home countries' Chief Medical Officers*. London: Department of Health.

Department of Health. (2012). Helping people live healthier lives: the future for public health. Retrieved from UK Goverment website:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216096/dh_127424.pdf

Dias, J. J., & Whitaker, R. C. (2013). Black mothers' perceptions about urban neighborhood safety and outdoor play for their preadolescent daughters. *J. Health Care Poor Underserved, 24*(1), 206-219.

Dobbins, M., Husson, H., DeCorby, K., & LaRocca, R. L. (2013). School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst Rev, 2*, CD007651. doi: 10.1002/14651858.CD007651.pub2

Doherty, A. R., Kelly, P., Kerr, J., Marshall, S., Oliver, M., Badland, H., . . . Foster, C. (2013). Using wearable cameras to categorise type and context of accelerometer-identified episodes of physical activity. *Int J Behav Nutr Phys Act, 10*, 22. doi: 10.1186/1479-5868-10-22

Dollman, J., Okely, A. D., Hardy, L., Timperio, A., Salmon, J., & Hills, A. P. (2009). A hitchhiker's guide to assessing young people's physical activity: Deciding what method to use. *J Sci Med Sport, 12*(5), 518-525. doi: 10.1016/j.jsams.2008.09.007

Donatiello, E., Dello Russo, M., Formisano, A., Lauria, F., Nappo, A., Reineke, A., . . . Siani, A. (2013). Physical activity, adiposity and urbanization level in children: results for the Italian cohort of the IDEFICS study. *Public Health, 127*(8), 761-765. doi: 10.1016/j.puhe.2013.04.031

Dumith, S. C., Gigante, D. P., Domingues, M. R., & Kohl, H. W. (2011). Physical activity change during adolescence: a systematic review and a pooled analysis. *Int J Epidemiol, 40*(3), 685-698. doi: 10.1093/ije/dyq272

Duncan, E. K., Duncan, J. S., & Schofield, G. (2008). Pedometer-determined physical activity and active transport in girls. *Int J Behav Nutr Phys Act, 5*, 9. doi: 10.1186/1479-5868-5-2

Duncan, S., Stewart, T. I., Oliver, M., Mavoa, S., MacRae, D., Badland, H. M., & Duncan, M. J. (2013). Portable global positioning system receivers: static validity and environmental conditions. *Am J Prev Med, 44*(2), e19-29. doi: 10.1016/j.amepre.2012.10.013

Dunton, G. F., Liao, Y., Intille, S., Wolch, J., & Pentz, M. A. (2011). Physical and social contextual influences on children's leisure-time physical activity: an ecological momentary assessment study. *J Phys Act Health, 8*(Suppl 1), S103-108.

Ekelund, U., Tomkinson, G., & Armstrong, N. (2011). What proportion of youth are physically active? Measurement issues, levels and recent time trends. *Br J Sports Med, 45*(11), 859-865. doi: 10.1136/bjsports-2011-090190

Ergler, C. R., Kearns, R. A., & Witten, K. (2013). Seasonal and locational variations in children's play: implications for wellbeing. *Soc Sci Med, 91*, 178-185. doi: 10.1016/j.socscimed.2012.11.034

Esliger, D., Copeland, J., Barnes, J., & Tremblay, M. (2005). Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. *J Phys Act Health, 2*(3), 366-383.

Eston, R. G., Rowlands, A. V., & Ingledew, D. K. (1998). Validity of heart rate, pedometry, and accelerometry for predicting the energy cost of children’s activities. *J Appl Physiol, 84*(1), 362-371.

Evenson, K. R., Catellier, D. J., Gill, K., Ondrak, K. S., & McMurray, R. G. (2008). Calibration of two objective measures of physical activity for children. *J Sports Sci, 26*(14), 1557-1565.

Fairclough, S. (2003a). Physical activity, perceived competence and enjoyment during high school physical education. *Eur Phys Educ Rev, 8*(1), 5-18. doi: 10.1080/1740898030080102

Fairclough, S., & Stratton, G. (2005a). Physical activity levels in middle and high school physical education: a review. *Pediatr Exerc Sci, 17*(3), 217-236.

Fairclough, S., & Stratton, G. (2005b). 'Physical education makes you fit and healthy'. Physical education's contribution to young people's physical activity levels. *Health Educ Res, 20*(1), 14-23. doi: 10.1093/her/cyg101

Fairclough, S. J. (2003b). Girls' physical activity during high school education: Influences of body composition and cardiorespiratory fitness. *J Teach Phys Educ, 22*(4), 382-395.

Falgairette, G., Gavarry, O., Bernard, T., & Hebbelinck, M. (1996). Evaluation of habitual physical activity from a week's heart rate monitoring in French school children. *Eur J Appl Physiol, 74*(1-2), 153-161.

Ferreira, I., van der Horst, K., Wendel-Vos, W., Kremers, S., van Lenthe, F. J., & Brug, J. (2007). Environmental correlates of physical activity in youth - a review and update. *Obes Rev, 8*(2), 129-154.

Field, A. (2013). *Discovering Statistics Using IBM SPSS Statistics* (4th ed.). London: SAGE Publications.

Fox, K. R. (2004). Childhood obesity and the role of physical activity. *J R Soc Promot Health, 124*(1), 34-39.

Fyhri, A., Hjorthol, R., Mackett, R. L., Fotel, T. N., & Kytta, M. (2011). Children's active travel and independent mobility in four countries: development, social contributing trends and measures. *Transport Policy, 18*(5), 703-710.

Gaster, S. (1991). Urban children's access to their neighborhood: changes over three generations. *Environ Behav, 23*(1), 70-85. doi: 10.1177/0013916591231004

Gidlow, C. J., Cochrane, T., Davey, R., Smith, H., Gidlow, C. J., Cochrane, T., . . . Smith, H. (2008). In-school and out-of-school physical activity in primary and secondary school children. *J Sports Sci, 26*(13), 1411-1419.

Giles-Corti, B., & King, A. C. (2009). Creating active environments across the life course: "thinking outside the square". *Br J Sports Med, 43*(2), 109-113.

Giles-Corti, B., Timperio, A., Bull, F., & Pikora, T. (2005a). Understanding physical activity environmental correlates: increased specificity for ecological models. *Exerc Sport Sci Rev, 33*(4), 175-181.

Giles-Corti, B., Timperio, A., Bull, F., & Pikora, T. (2005b). Understanding physical activity environmental correlates: Increased specificity for ecological models. *Exercise Sport Sci R, 33*(4), 175-181.

Global Advocacy for Physical Activity [GAPA] the Advocacy Council of the International Society for Physical Activity and Health [ISPAH]. (2011). NCD Prevention: Investments that Work for Physical Activity. Retrieved from ww.globalpa.orh.uk/investmentsthatwork

Gomez, J. E., Johnson, B. A., Selva, M., & Sallis, J. F. (2004). Violent crime and outdoor physical activity among inner-city youth. *Prev Med, 39*(5), 876-881. doi: 10.1016/j.ypmed.2004.03.019

Goodman, A., Mackett, R. L., & Paskins, J. (2011). Activity compensation and activity synergy in British 8-13 year olds. *Prev Med, 53*(4-5), 293-298. doi: 10.1016/j.ypmed.2011.07.019

Goodman, A., Paskins, J., & Mackett, R. (2012). Day length and weather effects on children's physical activity and participation in play, sports, and active travel. *J Phys Act Health, 9*(8), 1105-1116.

Goran, M. (1994). Application of the doubly labeled water technique for studying total energy expenditure in young children: A review. *Pediatr Exerc Sci, 6*(1), 11-30.

Guinhouya, B. C., Lemdani, M., Vilhelm, C., Hubert, H., Apete, G. K., Durocher, A., . . . Durocher, A. (2009). How school time physical activity is the "big one" for daily activity among schoolchildren: a semi-experimental approach. *J Phys Act Health, 6*(4), 510-519.

Hager, R. L. (2006). Television viewing and physical activity in children. *J Adolesc Health, 39*(5), 656-661. doi: 10.1016/j.jadohealth.2006.04.020

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet, 380*(9838), 247-257. doi: 10.1016/s0140-6736(12)60646-1

Hammond, D. E., McFarland, A. L., Zajicek, J. M., & Waliczek, T. M. (2011). Growing minds: the relationship between parental attitudes toward their child's outdoor recreation and their child's health. *Horttechnology, 21*(2), 217-224.

Hanggi, J. M., Phillips, L. R., & Rowlands, A. V. (2013). Validation of the GT3X ActiGraph in children and comparison with the GT1M ActiGraph. *J Sci Med Sport, 16*(1), 40-44. doi: 10.1016/j.jsams.2012.05.012

Hanley, J. A., & McNeil, B. J. (1982). The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology, 143*(1), 29-36.

Hardman, C. A., Horne, P. J., & Rowlands, A. V. (2009). Children's pedometer-determined physical activity during school-time and leisure-time. *J Exerc Sci Fit, 7*(2), 129-134.

Heath, R. (2014, October 14). Technology and Digital Health – the future for SEM?! Part two of a series from the RSM Exercise Medicine Conference, 2014. *BMJ Blogs*. Retrieved from BMJ Blogs website: http://blogs.bmj.com/

Helmerhorst, H. J., Brage, S., Warren, J., Besson, H., & Ekelund, U. (2012). A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. *Int J Behav Nutr Phys Act, 9*, 103. doi: 10.1186/1479-5868-9-103

Hillman, M. (2006). Children's rights and adults' wrongs. *Child Geogr, 4*(1), 61-67. doi: 10.1080/14733280600577418

Hillman, M., Adams, J., & Whitelegg, J. (1990). *One False Move: A Study of Children's Independent Mobility*. London: PSI Publishing.

Hjorthol, R., & Fyhri, A. (2009). Do organized leisure activities for children encourage car-use? *Transportation Res, 43*(2), 209-218. doi: 10.1016/j.tra.2008.11.005

Hohepa, M., Schofield, G., Kolt, G. S., Scragg, R., & Garrett, N. (2008). Pedometer-determined physical activity levels of adolescents: differences by age, sex, time of week, and transportation mode to school. *J Phys Act Health, 5*(Suppl 1), S140-152.

Holt, N. L., Spence, J. C., Sehn, Z. L., & Cutumisu, N. (2008). Neighborhood and developmental differences in children's perceptions of opportunities for play and physical activity. *Health Place, 14*(1), 2-14.

Humbert, M. L., Chad, K. E., Spink, K. S., Muhajarine, N., Anderson, K. D., Bruner, M. W., . . . Gryba, C. R. (2006). Factors that influence physical activity participation among high- and low-SES youth. *Qual Health Res, 16*(4), 467-483.

Jago, R., & Baranowski, T. (2004). Non-curricular approaches for increasing physical activity in youth: a review. *Prev Med, 39*(1), 157-163. doi: 10.1016/j.ypmed.2004.01.014

Jago, R., Page, A. S., & Cooper, A. R. (2012). Friends and physical activity during the transition from primary to secondary school. *Med Sci Sports Exerc, 44*(1), 111-117.

Jago, R., Thompson, J. L., Page, A. S., Brockman, R., Cartwright, K., & Fox, K. R. (2009). Licence to be active: parental concerns and 10-11-year-old children's ability to be independently physically active. *J Public Health (Oxf), 31*(4), 472-477.

Janssen, I., & Leblanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act, 7*, 40. doi: 10.1186/1479-5868-7-40

Jenkins, N. E. (2006). 'You can't wrap them up in cotton wool'! Constructing risk in young people's access to outdoor play. *Health Risk Soc, 8*(4), 379-393. doi: 10.1080/13698570601008289

Jimmy, G., Seiler, R., & Mäder, U. (2013). Comparing the validity and output of the GT1M and GT3X accelerometer in 5- to 9-year-old children. *Meas Phys Educ Exerc Sci, 17*(3), 236-248. doi: 10.1080/1091367x.2013.805140

Johansson, M. (2006). Environment and parental factors as determinants of mode for children's leisure travel. *J Environ Pscyhol, 26*(2), 156-169. doi: 10.1016/j.jenvp.2006.05.005

Jones, A. P., Bentham, G., Foster, C., Hillsdon, M., & Panter, J. (2007). Tackling obesities: future choices–obesogenic environment–evidence review. London: Government Office for Science.

Jones, A. P., Coombes, E. G., Griffin, S. J., & van Sluijs, E. M. F. (2009). Environmental supportiveness for physical activity in English schoolchildren: a study using Global Positioning Systems. *Int J Behav Nutr Phys Act, 6*, 42. doi: 10.1186/1479-5868-6-42

Kalish, M., Banco, L., Burke, G., & Lapidus, G. (2010). Outdoor play: a survey of parent's perceptions of their child's safety. *J Trauma, 69*(4), s218-s222.

Kantomaa, M. T., Tammelin, T. H., Nayha, S., & Taanila, A. M. (2007). Adolescents' physical activity in relation to family income and parents' education. *Prev Med, 44*(5), 410-415.

Karsten, L. (2005). It all used to be better? Different generations on continuity and change in urban children's daily use of space. *Child Geogr, 3*(3), 275-290. doi: 10.1080/14733280500352912

Katzmarzyk, P. T., & Malina, R. M. (1998). Contribution of organized sports participation to estimated daily energy expenditure in youth. *Pediatr Exerc Sci, 10*(4), 378-386.

Katzmarzyk, P. T., Walker, P., & Malina, R. M. (2001). A time-motion study or organized youth sports. *J Hum Movement Stud, 40*(1231), 325-334.

Kerr, J., Duncan, S., & Schipperjin, J. (2011). Using global positioning systems in health research: a practical approach to data collection and processing. *Am J Prev Med, 41*(5), 532-540. doi: 10.1016/j.amepre.2011.07.017

Kilanowski, C. K., Consalvi, A. R., & Epstein, L. H. (1999). Validation of an electronic pedometer for measurement of physical activity in children. *Pediatr Exerc Sci, 11*(1), 63-68.

Kimbro, R. T., Brooks-Gunn, J., & McLanahan, S. (2011). Young children in urban areas: links among neighborhood characteristics, weight status, outdoor play, and television watching. *Soc Sci Med, 72*(5), 668-676.

Kirkwood, B., & Sterne, J. (2003). *Essential Medical Statistics* (2nd edition ed.). Oxford: Blackwell Science Ltd.

Klasson-Heggebo, L., & Anderssen, S. A. (2003). Gender and age differences in relation to the recommendations of physical activity among Norwegian children and youth. *Scand J Med Sci Sports, 13*(5), 293-298.

Klinker, C. D., Schipperijn, J., Christian, H., Kerr, J., Ersboll, A. K., & Troelsen, J. (2014a). Using accelerometers and global positioning system devices to assess gender and age differences in children's school, transport, leisure and home based physical activity. *Int J Behav Nutr Phys Act, 11*, 8. doi: 10.1186/1479-5868-11-8

Klinker, C. D., Schipperijn, J., Kerr, J., Ersboll, A. K., & Troelsen, J. (2014b). Context-specific outdoor time and physical activity among school-children across gender and age: using accelerometers and GPS to advance methods. *Front Public Health, 2*, 20. doi: 10.3389/fpubh.2014.00020

Kohl, H. W., 3rd, Craig, C. L., Lambert, E. V., Inoue, S., Alkandari, J. R., Leetongin, G., & Kahlmeier, S. (2012). The pandemic of physical inactivity: global action for public health. *Lancet, 380*(9838), 294-305. doi: 10.1016/s0140-6736(12)60898-8

Kohl, H. W., Fulton, J. E., & Caspersen, C. J. (2000). Assessment of physical activity among children and adolescents: a review and synthesis. *Prev Med, 31*(2), S54-76.

Kremers, S., de Bruijn, G.-J., Visscher, T., van Mechelen, W., de Vries, N., & Brug, J. (2006). Environmental influences on energy balance-related behaviors: A dual-process view. *Int J Behav Nutr Phys Act, 3*, 9. doi: 10.1186/1479-5868-3-9

Kytta, M. (2004). The extent of children's independent mobility and the number of actualized affordances as criteria for child-friendly environments. *J Environ Psychol, 24*(2), 179-198. doi: 10.1016/S0272-4944(03)00073-2

Lam, M. S., Godbole, S., Chen, J., Oliver, M., Badland, H., Marshall, S. J., . . . Kerr, J. (2013). *Measuring time spent outdoors using a wearable camera and GPS*. Paper presented at the Proceedings of the 4th International SenseCam & Pervasive Imaging Conference, San Diego, California, USA.

Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., & Katzmarzyk, P. T. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet, 380*(9838), 219-229. doi: 10.1016/s0140-6736(12)61031-9

Leek, D., Carlson, J. A., Cain, K. L., Henrichon, S., Rosenberg, D., Patrick, K., & Sallis, J. F. (2011). Physical activity during youth sports practices. *Arch Pediatr Adolesc Med, 165*(4), 294-299. doi: 10.1001/archpediatrics.2010.252

Levin, S., McKenzie, T. L., Hussey, J. R., Kelder, S. H., & Lytle, L. A. (2001). Variability of physical activity during physical education lessons across elementary school grades. *Meas Phys Educ Exerc Sci, 5*(4), 207-218. doi: 10.1207/s15327841mpee0504_02

Lewis, A., & Lindsay, G. (2000). *Research Children's Perspectives*. Buckingham, UK: Open University Press.

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., . . . Ezzati, M. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet, 380*(9859), 2224-2260. doi: 10.1016/s0140-6736(12)61766-8

Livingstone, M. B., Coward, W. A., Prentice, A. M., Davies, P. S., Strain, J. J., McKenna, P. G., . . . Kerr, M. J. (1992). Daily energy expenditure in free-living children: comparison of heart-rate monitoring with the doubly labeled water (2H2(18)O) method. *Am J Clin Nutr, 56*(2), 343-352.

Loucaides, C. A., & Jago, R. (2008). Differences in physical activity by gender, weight status and travel mode to school in Cypriot children. *Prev Med, 47*(1), 107-111. doi: 10.1016/j.ypmed.2008.01.025

Mackett, R., Brown, B., Gong, Y., Kitazawa, K., & Paskins, J. (2007). Children's independent movement in the local environment. *Built Environ, 33*(4), 454-468.

Mackett, R. L., & Paskins, J. (2008). Children's physical activity: the contribution of playing and walking. *Child Soc, 22*(5), 345-357. doi: 10.1111/j.1099-0860.2007.00113.x

Maddison, R., Jiang, Y., Vander Hoorn, S., Exeter, D., Mhurchu, C. N., & Dorey, E. (2010). Describing patterns of physical activity in adolescents using global positioning systems and accelerometry. *Pediatr Exerc Sci, 22*(3), 392-407.

Maddison, R., & Ni Mhurchu, C. (2009). Global positioning system: a new opportunity in physical activity measurement. *Int J Behav Nutr Phys Act, 6*, 73. doi: 10.1186/1479-5868-6-73

Maher, C. A., & Olds, T. S. (2009). Minutes, MET minutes, and METs: unpacking socio-economic gradients in physical activity in adolescents. *Journal Epidemiol Commun H, 65*(2), 160-165. doi: 10.1136/jech.2009.099796

Maldonado, G., & Greenland, S. (1993). Simulation study of confounder-selection strategies. *Am J Epidemiol, 138*(11), 923-936.

Marshall, J., & Hardman, K. (2000). The state and status of physical education in schools in international context. *European Physical Education Review, 6*(3), 203-229. doi: 10.1177/1356336x000063001

Martinez-Gomez, D., Calabro, M. A., Welk, G. J., Marcos, A., & Veiga, O. L. (2010). Reliability and validity of a school recess physical activity recall in Spanish youth. *Pediatr Exerc Sci, 22*(2), 218-230.

Masse, L. C., Fuemmeler, B. F., Anderson, C. B., Matthews, C. E., Trost, S. G., Catellier, D. J., & Treuth, M. (2005). Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. *Med Sci Sports Exerc, 37*(11 Suppl), S544-554.

McClain, J. J., Abraham, T. L., Brusseau, T. A., Jr., & Tudor-Locke, C. (2008). Epoch length and accelerometer outputs in children: comparison to direct observation. *Med Sci Sports Exerc, 40*(12), 2080-2087.

McKenna, J., Foster, L. J., & Page, A. S. (2004). Exploring recall of physical activity in young people using qualitative interviewing. *Pediatr Exerc Sci, 16*(1), 5-14.

McKenzie, T. L. (2002). The use of direct observation to assess physical activity. In G. J. Welk (Ed.), *Physical activity assessments for health-related research* (pp. 179-195). Champaign, IL: Human Kinetics.

McKenzie, T. L., Catellier, D. J., Conway, T., Lytle, L. A., Grieser, M., Webber, L. A., . . . Elder, J. P. (2006). Girls' activity levels and lesson contexts in middle school PE: TAAG baseline. *Med Sci Sports Exerc, 38*(7), 1229-1235. doi: 10.1249/01.mss.0000227307.34149.f3

McKenzie, T. L., Marshall, S. J., Sallis, J. F., & Conway, T. L. (2000). Leisure-time physical activity in school environments: an observational study using SOPLAY. *Prev Med, 30*(1), 70-77. doi: 10.1006/pmed.1999.0591

McKenzie, T. L., Prochaska, J. J., Sallis, J. F., & LaMaster, K. J. (2004). Coeducational and single-sex physical education in middle schools: impact on physical activity. *Res Q Exerc Sport, 75*(4), 446-449.

McMillan, T. E. (2005). Urban form and a child’s trip to school: The current literature and a framework for future research. *J Plan Lit, 19*(4), 440-456. doi: 10.1177/0885412204274173

McMinn, A. M., Griffin, S. J., Jones, A. P., & van Sluijs, E. M. F. (2013). Family and home influences on children’s after-school and weekend physical activity. *Eur J Public Health, 23*(5), 805-810. doi: 10.1093/eurpub/cks160

Mendonca, G., Cheng, L. A., Melo, E. N., & de Farias Junior, J. C. (2014). Physical activity and social support in adolescents: a systematic review. *Health Educ Res, 29*(5), 822-839.

Metallinos-Katsaras, E. S., Freedson, P. S., Fulton, J. E., & Sherry, B. (2007). The association between an objective measure of physical activity and weight status in preschoolers. *Obesity 15*(3), 686-694. doi: 10.1038/oby.2007.571

Metz, C. E. (1978). Basic principles of ROC analysis. *Semin Nucl Med, 8*(4), 283-298. doi: 10.1016/s0001-2998(78)80014-2

Mikkelsen, M. R., & Christensen, P. (2009). Is children's independent mobility really independent? A study of children's mobility combining ethnography and GPS/mobile phone technologies. *Mobilities, 4*(1), 37-58.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., . . . Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev, 4*(1), 2046-4053.

Moore, H. J., Nixon, C. A., Lake, A. A., Douthwaite, W., O'Malley, C. L., Pedley, C. L., . . . Routen, A. C. (2014). The environment can explain differences in adolescents' daily physical activity levels living in a deprived urban area: cross-sectional study using accelerometry, GPS and focus groups. *J Phys Act Health, [Epub ahead of print]*. doi: 10.1123/jpah.2012-0420

Moss, S. (2012). Natural Childhood. London: National Trust.

Mota, J., Santos, P., Guerra, S., Ribeiro, J. C., Duarte, J. A., Mota, J., . . . Duarte, J. A. (2003). Patterns of daily physical activity during school days in children and adolescents. *Am J Hum Biol, 15*(4), 547-553.

Mota, J., Silva, P., Santos, M. P., Ribeiro, J. C., Oliveira, J., & Duarte, J. A. (2005). Physical activity and school recess time: differences between the sexes and the relationship between children's playground physical activity and habitual physical activity. *J Sports Sci, 23*(3), 269-275. doi: 10.1080/02640410410001730124

Nader, P. R. (2003). Frequency and intensity of activity of third-grade children in physical education. *Arch Pediatr Adolesc Med, 157*(2), 185-190.

Nader, P. R., Bradley, R. H., Houts, R. M., McRitchie, S. L., & O'Brien, M. (2008). Moderate-to-vigorous physical activity from ages 9 to 15 years. *JAMA, 300*(3), 295-305. doi: 10.1001/jama.300.3.295

Nilsson, A., Andersen, L. B., Ommundsen, Y., Froberg, K., Sardinha, L. B., Piehl-Aulin, K., & Ekelund, U. (2009). Correlates of objectively assessed physical activity and sedentary time in children: a cross-sectional study (The European Youth Heart Study). *BMC Publ Health, 9*, 322. doi: 10.1186/1471-2458-9-322

Nyberg, G. A., Nordenfelt, A. M., Ekelund, U., & Marcus, C. (2009). Physical activity patterns measured by accelerometry in 6-to 10-yr-old children. *Med Sci Sports Exerc, 41*(10), 1842-1848.

O'Brien, J., & Smith, J. (2002). Childhood transformed? Risk perceptions and the decline of free play. *Br J Occup Ther, 65*(3), 123-128.

O'Brien, M., Jones, D., Sloan, D., & Rustin, M. (2000). Children's independent spatial mobility in the urban public realm. *Childhood, 7*(3), 257-277.

Ofcom. (2012). Children’s TV viewing: BARB analysis. Retrieved from Ofcom website: http://stakeholders.ofcom.org.uk

Oliver, M., Badland, H., Mavoa, S., Duncan, M. J., & Duncan, S. (2010). Combining GPS, GIS, and accelerometry: methodological issues in the assessment of location and intensity of travel behaviors. *J Phys Act Health, 7*(1), 102-108.

Page, A., Cooper, A. R., Stamatakis, E., Foster, L. J., Crowne, E. C., Sabin, M., . . . Shield, J. P. H. (2005). Physical activity patterns in nonobese and obese children assessed using minute-by-minute accelerometry. *Int J Obesity, 29*(9), 1070-1076.

Page, A. S., Cooper, A. R., Griew, P., Davis, L., & Hillsdon, M. (2009). Independent mobility in relation to weekday and weekend physical activity in children aged 10-11 years: the PEACH project. *Int J Behav Nutr Phys Act, 6*, 2. doi: 10.1186/1479-5868-6-2

Page, A. S., Cooper, A. R., Griew, P., & Jago, R. (2010). Independent mobility, perceptions of the built environment and children's participation in play, active travel and structured exercise and sport: the PEACH project. *Int J Behav Nutr Phys Act, 7*, 17. doi: 10.1186/1479-5868-7-17

Page, A. S., Cooper, A. R., McKenna, J., Foster, L. J., Riddoch, C. J., & Fox, K. R. (2000). Development of a research tool to measure physical activity among young people aged 5-16 in the UK. *Meas Phys Educ Exerc Sci, 4*, 267-268.

Panter, J. R., Jones, A. P., & van Sluijs, E. M. F. (2008). Environmental determinants of active travel in youth: a review and framework for future research. *Int J Behav Nutr Phys Act, 5*, 34. doi: 10.1186/1479-5868-5-34

Pate, R. R., Pratt, M., Blair, S. N., Haskell, W. L., Macera, C. A., Bouchard, C., . . . et al. (1995). Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA, 273*(5), 402-407.

Payne, S., Townsend, N., & Foster, C. (2013). The physical activity profile of active children in England. *Int J Behav Nutr Phys Act, 10*, 136. doi: 10.1186/1479-5868-10-136

Peeters, G., van Gellecum, Y., Ryde, G., Farias, N. A., & Brown, W. J. (2013). Is the pain of activity log-books worth the gain in precision when distinguishing wear and non-wear time for tri-axial accelerometers? *J Sci Med Sport, 16*(6), 515-519. doi: 10.1016/j.jsams.2012.12.002

Pooley, C. G., Turnbull, J., & Adams, M. (2005). The journey to school in Britain since the 1940s: continuity and change. *Area, 37*(1), 43-53. doi: 10.1111/j.1475-4762.2005.00605.x

Pratt, M., Macera, C. A., Sallis, J. F., O'Donnell, M., & Frank, L. D. (2004). Economic interventions to promote physical activity: application of the SLOTH model. *Am J Prev Med, 27*(3 Suppl), 136-145. doi: 10.1016/j.amepre.2004.06.015

Prezza, M., Alparone, F. R., Renzi, D., & Pietrobono, A. (2010). Social participation and independent mobility in children: the effects of two implementations of "we go to school alone". *Journal of prevention & intervention in the community, 38*(1), 8-25.

Prezza, M., Pilloni, S., Morabito, C., Sersante, C., Alparone, F. R., & Giuliani, M. V. (2001). The influence of psychosocial and environmental factors on children's independent mobility and relationship to peer frequentation. *J Community Appl Soc Psychol, 11*(6), 435-450.

Prochaska, J. O., & Marcus, B. H. (1994). The transtheoretical model: applications to exercise. In R. K. Dishman (Ed.), *Advances in Exercise Adherence* (pp. 161 - 180). Champaign, IL: Human Kinetics.

Puyau, M. R., Adolph, A. L., Vohra, F. A., & Butte, N. F. (2002). Validation and calibration of physical activity monitors in children. *Obes Res, 10*(3), 150-157. doi: 10.1038/oby.2002.24

Rainham, D. G., Bates, C. J., Blanchard, C. M., Dummer, T. J., Kirk, S. F., & Shearer, C. L. (2012). Spatial classification of youth physical activity patterns. *Am J Prev Med, 42*(5), e87-96. doi: 10.1016/j.amepre.2012.02.011

Reilly, J. J., Penpraze, V., Hislop, J., Davies, G., Grant, S., & Paton, J. Y. (2008). Objective measurement of physical activity and sedentary behaviour: review with new data. *Arch Dis Child, 93*(7), 614-619. doi: 10.1136/adc.2007.133272

Rennie, K. L., & Wareham, N. J. (1998). The validation of physical activity instruments for measuring energy expenditure: problems and pitfalls. *Public Health Nutr, 1*(4), 265-271.

Rich, C., Geraci, M., Griffiths, L., Sera, F., Dezateux, C., & Cortina-Borja, M. (2013). Quality control methods in accelerometer data processing: defining minimum wear time. *PLoS One, 8*(6), e67206. doi: 10.1371/journal.pone.0067206

Riddoch, C. J., Bo Andersen, L., Wedderkopp, N., Harro, M., Klasson-Heggebo, L., Sardinha, L. B., . . . Ekelund, U. (2004). Physical activity levels and patterns of 9- and 15-yr-old European children. *Med Sci Sports Exerc, 36*(1), 86-92. doi: 10.1249/01.mss.0000106174.43932.92

Riddoch, C. J., Mattocks, C., Deere, K., Saunders, J., Kirkby, J., Tilling, K., . . . Ness, A. R. (2007). Objective measurement of levels and patterns of physical activity. *Arch Dis Child, 92*(11), 963-969.

Ridgers, N. D., Graves, L. E. F., Foweather, L., & Stratton, G. (2010). Examining influences on boy's and girls' physical activity patterns: the A-CLASS Project. *Pediatr Exerc Sci, 22*(4), 638-650.

Ridgers, N. D., Stratton, G., & Fairclough, S. J. (2005). Assessing physical activity during recess using accelerometry. *Prev Med, 41*(1), 102-107.

Ridley, K., Ainsworth, B. E., & Olds, T. S. (2008). Development of a compendium of energy expenditures for youth. *Int J Behav Nutr Phys Act, 5*, 45. doi: 10.1186/1479-5868-5-45

Rodriguez, D. A., Brown, A. L., & Troped, P. J. (2005). Portable global positioning units to complement accelerometry-based physical activity monitors. *Med Sci Sports Exerc, 37*(11 Suppl), S572-581.

Rowlands, A. V., & Eston, R. G. (2007). The measurement and interpretation of children's physical activity. *J Sport Sci Med, 6*(3), 270-276.

Rowlands, A. V., Eston, R. G., & Ingledew, D. K. (1997). Measurement of physical activity in children with particular reference to the use of heart rate and pedometry. *Sports Med, 24*(4), 258-272.

Rowlands, A. V., & Hughes, D. R. (2006). Variability of physical activity patterns by type of day and season in 8-10-year-old boys. *Res Q Exerc Sport, 77*(3), 391-395.

Sallis, J. F., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K., & Kerr, J. (2006). An ecological approach to creating active living communities. *Annu Rev Public Health, 27*, 297-322.

Sallis, J. F., & Owen, N. (1999). *Physical activity and behavioral medicine*. Thousand Oaks, CA: Sage Publications.

Sallis, J. F., Owen, N., & Fisher, E. B. (2008). Ecological Models of Health Behaviour. In K. Glanz, Rimer, B.K. and Lewis, F.M. (Ed.), *Health Behaviour and Health Education: Theory, Research and Practice* (pp. 465 - 483). San Francisco, CA: Jossey Bass.

Sallis, J. F., Owen, N., & Fotheringham, M. J. (2000a). Behavioral epidemiology: a systematic framework to classify phases of research on health promotion and disease prevention. *Ann Behav Med, 22*(4), 294-298.

Sallis, J. F., Prochaska, J. J., & Taylor, W. C. (2000b). A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc, 32*(5), 963-975.

Sallis, J. F., & Saelens, B. E. (2000). Assessment of physical activity by self-report: status, limitations, and future directions. *Res Q Exerc Sport, 71*(2 Suppl), S1-14.

Salmon, J., Booth, M. L., Phongsavan, P., Murphy, N., & Timperio, A. (2007). Promoting physical activity participation among children and adolescents. *Epidemiol Rev, 29*, 144-159. doi: 10.1093/epirev/mxm010

Sasaki, J. E., John, D., & Freedson, P. S. (2011). Validation and comparison of ActiGraph activity monitors. *J Sci Med Sport, 14*(5), 411-416. doi: 10.1016/j.jsams.2011.04.003

Scarborough, P., Bhatnagar, P., Wickramasinghe, K. K., Allender, S., Foster, C., & Rayner, M. (2011). The economic burden of ill health due to diet, physical inactivity, smoking, alcohol and obesity in the UK: an update to 2006-07 NHS costs. *J Public Health (Oxf), 33*(4), 527-535. doi: 10.1093/pubmed/fdr033

Schisterman, E. F., Cole, S. R., & Platt, R. W. (2009). Overadjustment bias and unnecessary adjustment in epidemiologic studies. *Epidemiology 20*(4), 488-495. doi: 10.1097/EDE.0b013e3181a819a1

Schoeller, D. A., Ravussin, E., Schutz, Y., Acheson, K. J., Baertschi, P., & Jequier, E. (1986). Energy expenditure by doubly labeled water: validation in humans and proposed calculation. *Am J Physiol, 250*(5 Pt 2), R823-830.

Scruggs, P. W., Beveridge, S. K., Eisenman, P. A., Watson, D. L., Shultz, B. B., & Ransdell, L. B. (2003). Quantifying physical activity via pedometry in elementary physical education. *Med Sci Sports Exerc, 35*(6), 1065-1071. doi: 10.1249/01.mss.0000069748.02525.b2

Shavers, V. L. (2007). Measurement of socioeconomic status in health disparities research. *J Natl Med Assoc, 99*(9), 1013-1023.

Singh, A. (2014, July 11). Most children 'play outside for less than an hour a day'. *The Telegraph*. Retrieved from The Telegraph website: http://www.telegraph.co.uk

Sirard, J. R., Kubik, M. Y., Fulkerson, J. A., & Arcan, C. (2008). Objectively measured physical activity in urban alternative high school students. *Med Sci Sports Exerc, 40*(12), 2088-2095. doi: 10.1249/MSS.0b013e318182092b

Sirard, J. R., & Pate, R. R. (2001). Physical activity assessment in children and adolescents. *Sports Med, 31*(6), 439-454.

Soori, H. (2006). Childrens's indoor and outdoor play patterns in Ahwaz city: implications for injury prevention. *East Mediterr Health J, 12*(3), 372-381.

Soori, H., & Bhopal, R. S. (2002). Parental permission for children's independent outdoor activities. Implications for injury prevention. *Eur J Public Health, 12*(2), 104-109.

Southward, E. F., Page, A. S., Wheeler, B. W., & Cooper, A. R. (2012). Contribution of the school journey to daily physical activity in children aged 11–12 years. *Am J Prev Med, 43*(2), 201-204.

Spink, K. S., Shields, C. A., Chad, K., Odnokon, P., Muhajarine, N., & Humbert, L. (2006). Correlates of structured and unstructured activity among sufficiently active youth and adolescents: a new approach to understanding physical activity. *Pediatr Exerc Sci, 18*(2), 203-215.

Sport England. (2012). School Games Executive Summary. Retrieved from Sport England website: http://www.sportengland.org

Stone, E. J., McKenzie, T. L., Welk, G. J., & Booth, M. L. (1998). Effects of physical activity interventions in youth. Review and synthesis. *Am J Prev Med, 15*(4), 298-315.

Stone, M. R., & Faulkner, G. E. (2014). Outdoor play in children: associations with objectively-measured physical activity, sedentary behavior and weight status. *Prev Med, 65*, 122-127. doi: 10.1016/j.ypmed.2014.05.008

Stratton, G., & Mullan, E. (2005). The effect of multicolor playground markings on children's physical activity level during recess. *Prev Med, 41*(5-6), 828-833.

Stratton, G., Ridgers, N. D., Fairclough, S. J., & Richardson, D. J. (2007). Physical activity levels of normal-weight and overweight girls and boys during primary school recess. *Obesity, 15*(6), 1513-1519.

Streiner, D. L. (2002). Breaking up is hard to do: the heartbreak of dichotomizing continuous data. *Can J Psychiatry, 47*(3), 262-266.

Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., . . . Trudeau, F. (2005). Evidence based physical activity for school-age youth. *J Pediatr, 146*(6), 732-737. doi: 10.1016/j.jpeds.2005.01.055

Tandon, P. S., Saelens, B. E., Zhou, C., Kerr, J., & Christakis, D. A. (2013). Indoor versus outdoor time in preschoolers at child care. *Am J Prev Med, 44*(1), 85-88. doi: 10.1016/j.amepre.2012.09.052

Thomson, J. L., & Philo, C. (2004). Playful spaces? A social geography of children's play in Livingston, Scotland. *Child Geogr, 2*(1), 111-130. doi: 10.1080/1473328032000168804

Timperio, A., Crawford, D., Telford, A., & Salmon, J. (2004). Perceptions about the local neighborhood and walking and cycling among children. *Prev Med, 38*(1), 39-47. doi: 10.1016/j.ypmed.2003.09.026

Toftager, M., Kristensen, P. L., Oliver, M., Duncan, S., Christiansen, L. B., Boyle, E., . . . Troelsen, J. (2013). Accelerometer data reduction in adolescents: effects on sample retention and bias. *Int J Behav Nutr Phys Act, 10*, 140. doi: 10.1186/1479-5868-10-140

Tremblay, M. S., Colley, R. C., Saunders, T. J., Healy, G. N., & Owen, N. (2010). Physiological and health implications of a sedentary lifestyle. *Appl Physiol Nutr Metab, 35*(6), 725-740. doi: 10.1139/h10-079

Treuth, M. S., Catellier, D. J., Schmitz, K. H., Pate, R. R., Elder, J. P., McMurray, R. G., . . . Webber, L. (2007). Weekend and weekday patterns of physical activity in overweight and normal-weight adolescent girls. *Obesity, 15*(7), 1782-1788.

Troiano, R. P., Berrigan, D., Dodd, K. W., Masse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc, 40*(1), 181-188. doi: 10.1249/mss.0b013e31815a51b3

Trost, S. G. (2007). State of the art reviews: measurement of physical activity in children and adolescents. *Am J Lifestyle Med, 1*(4), 299-314. doi: 10.1177/1559827607301686

Trost, S. G., Loprinzi, P. D., Moore, R., & Pfeiffer, K. A. (2011). Comparison of accelerometer cut points for predicting activity intensity in youth. *Med Sci Sports Exerc, 43*(7), 1360-1368.

Trost, S. G., McIver, K. L., & Pate, R. R. (2005). Conducting accelerometer-based activity assessments in field-based research. *Med Sci Sports Exerc, 37*(11 Suppl), S531-543.

Trost, S. G., Morgan, A. M., Saunders, R., Felton, G., Ward, D. S., & Pate, R. R. (2000a). Children's understanding of the concept of physical activity. *Pediatr Exerc Sci, 12*(3), 293-299.

Trost, S. G., Pate, R. R., Freedson, P. S., Sallis, J. F., & Taylor, W. C. (2000b). Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc, 32*(2), 426-431.

Trost, S. G., Rosenkranz, R. R., & Dzewaltowski, D. (2008). Physical activity levels among children attending after-school programs. *Med Sci Sports Exerc, 40*(4), 622-629. doi: 10.1249/MSS.0b013e318161eaa5

Tudor-Locke, C., Ainsworth, B. E., Adair, L. S., & Popkin, B. M. (2003). Objective physical activity of Filipino youth stratified for commuting mode to school. *Med Sci Sports Exerc, 35*(3), 465-471. doi: 10.1249/01.mss.0000053701.30307.a6

Tudor-Locke, C., Neff, L. J., Ainsworth, B. E., Addy, C. L., & Popkin, B. M. (2002). Omission of active commuting to school and the prevalence of children's health-related physical activity levels: the Russian Longitudinal Monitoring Study. *Child Care Health Dev, 28*(6), 507-512.

United Nations General Assembly. (1989). *United Nations Convention on the Rights of the Child*. Geneva: Office of the United Nations High Commissioner for Human Rights.

US Department of Health and Human Services. (2000). Healthy People 2010. Retrieved from Centers for Disease Control and Prevention website: http://www.cdc.gov

US Department of Health and Human Services. (2008). *2008 Physical Activity Guidelines for Americans*. US Department of Health and Human Services Retrieved from http://www.health.gov.

Valentine, G. (1997). "Oh yes I can." "oh no you can't": Children and parents' understandings of kids' competence to negotiate public space safely. *Antipode, 29*(1), 65-89.

Valentine, G., & McKendrick, J. (1997). Children's outdoor play: Exploring parental concerns about children's safety and the changing nature of childhood. *Geoforum, 28*(2), 219-235. doi: 10.1016/s0016-7185(97)00010-9 van Sluijs, E. M. F., McMinn, A. M., & Griffin, S. (2007). Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. *BMJ, 335*(7622), 703-707.

Veitch, J., Bagley, S., Ball, K., & Salmon, J. (2006). Where do children usually play? A qualitative study of parents' perceptions of influences on children's active free-play. *Health Place, 12*(4), 383-393.

Veitch, J., Salmon, J., & Ball, K. (2007). Children's perceptions of the use of public open spaces for active free-play. *Child Geogr, 5*(4), 409-422. doi: 10.1080/14733280701631874

Veitch, J., Salmon, J., & Ball, K. (2008). Children's active free play in local neighborhoods: a behavioral mapping study. *Health Educ Res, 23*(5), 870-879.

Veitch, J., Salmon, J., & Ball, K. (2010). Individual, social and physical environmental correlates of children's active free-play: a cross-sectional study. *Int J Behav Nutr Phys Act, 7*, 11. doi: 10.1186/1479-5868-7-11

Vincent, S. D., & Pangrazi, R. P. (2002). An examination of the activity patterns of elementary school children. *Pediatr Exerc Sci, 14*(4), 432-441.

Weiler, R., Allardyce, S., Whyte, G. P., & Stamatakis, E. (2014). Is the lack of physical activity strategy for children complicit mass child neglect? *Br J Sports Med, 48*(13), 1010-1013. doi: 10.1136/bjsports-2013-093018

Weir, L. A., Etelson, D., & Brand, D. A. (2006). Parents' perceptions of neighborhood safety and children's physical activity. *Prev Med, 43*(3), 212-217. doi: 10.1016/j.ypmed.2006.03.024

Welk, G. J., Corbin, C. B., & Dale, D. (2000). Measurement issues in the assessment of physical activity in children. *Res Q Exerc Sport, 71*(2 Suppl), S59-73.

Wen, L. M., Kite, J., Merom, D., & Rissel, C. (2009). Time spent playing outdoors after school and its relationship with independent mobility: a cross-sectional survey of children aged 10-12 years in Sydney, Australia. *Int J Behav Nutr Phys Act, 6*, 15. doi: 10.1186/1479-5868-6-15

Wheeler, B. W., Cooper, A. R., Page, A. S., & Jago, R. (2010). Greenspace and children's physical activity: a GPS/GIS analysis of the PEACH project. *Prev Med, 51*(2), 148-152.

Wickel, E. E., & Eisenmann, J. C. (2007). Contribution of youth sport to total daily physical activity among 6-to 12-yr-old boys. *Med Sci Sports Exerc, 39*(9), 1493-1500.

Witten, K., Kearns, R., Carroll, P., Asiasiga, L., & Tava'e, N. (2013). New Zealand parents' understandings of the intergenerational decline in children's independent outdoor play and active travel. *Childrens Geographies, 11*(2), 215-229. doi: 10.1080/14733285.2013.779839

World Health Organization. (2009). Global health risks: mortality and burden of disease attributable to selected major risks. Retrieved from World Health Organization website: http://www.who.int

World Health Organization. (2010). Global Recommendations on Physical Activity for Health. Retrieved from World Health Organization website: http://www.who.int

Worobey, J., Fonseca, D. M., Espinosa, C., Healy, S., & Gaugler, R. (2013). Child outdoor physical activity is reduced by prevalence of the Asian Tiger Mosquito, Aedes albopictus. *J Am Mosq Control Assoc, 29*(1), 78-80.

Ziviani, J., Wadley, D., Ward, H., Macdonald, D., Jenkins, D., & Rodger, S. (2008). A place to play: socioeconomic and spatial factors in children's physical activity. *Aust Occup Ther J, 55*(1), 2-11. doi: 10.1111/j.1440-1630.2006.00646.x

# Appendix A

Materials for Chapter Five:

1. Example of diary used in Personal and Environmental Associations with Children's Health (PEACH) project.

# My Activity Diary

**Diary Dates:**

From: _ _ _ _ _ _ _ _ _ _  MALE

To: _ _ _ _ _ _ _ _ _ _  FEMALE

| Pupil ID | |
|---|---|

Here is an **EXAMPLE** of how to fill in the table in your activity diary –
**Remember your answers will be different**

| What did you do after school? | What time did you start this? | What time did you finish this? | Were you inside or outside? (please circle) | | Who were you with? (please circle) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | On my own | a friend | brother / sister | mum or dad | another grown up |
| The first thing I did was...... *Walked home from school* | *3.15* | *3.30* | IN | OUT | | | | | |
| Then I..... *Did my homework* | *3.30* | *4.15* | IN | OUT | | | | | |
| Then I..... *Played a game of swingball* | *4.15* | *4.45* | IN | OUT | | | | | |

# Appendix B

Materials for Chapter Six:

1. Participant information sheet.
2. Participant informed consent.

## PARTICIPANT INFORMATION SHEET

**PROJECT TITLE**
Using Global Positioning Systems (GPS) to determine time spent outdoors.

**BACKGROUND**
The main focus of my PhD work concerns the physical activity levels of children, and how these relate to contextual factors such as time spent indoors and outdoors. Accurate, objective measurement tools are important for accurately describing the volume and context of physical activity. Using the output from GPS receivers, time outdoors can be estimated. At present the data processing steps required to produce an estimate of time outdoors are unclear. As such, the estimate of time outdoors using GPS must be compared to a known criterion standard, in this case, direct observation of the participant.

**WHAT WILL HAPPEN**
In this study, the GPS device will be trialled in adult participants carrying out normal daily activities. There is no trial, exercise or invasive procedure to be completed. As such the risks of involvement are minimal; however participants should be remain aware of normal day-to-day hazards during involvement (e.g. traffic). Participants will be asked to a Qstarz GPS data logger to measure position every five seconds. The device is small, light and easily fastened using an elastic belt.

Participant location will also be directly observed by an investigator. This means that the participant will need to be visible to the observer at all times during the observation period. Contextual information (indoors/outdoors) will be recorded. It is therefore important that participants will be located within Edinburgh on the measurement day. Since the aim of the study is to investigate how the device records time spent outdoors, it is important that participants will be moving in and out of buildings during the measurement period. The study has received ethical approval from the Moray House School of Education Ethics Committee.

**TIME COMMITMENT**
The study requires that participants be available for observation for at least five hours on at least one day, preferably at a time when it is expected that participants will be moving in and out of buildings.

**PARTICIPANTS' RIGHTS**
Participation in this study is voluntary. Participants may decide to stop being a part of the research study at any time without explanation. Participants have the right to ask that any data supplied be withdrawn. Participants have the right to have questions about the procedures answered. If participants have any questions as a result of reading this information sheet, they should ask the researcher before the study begins.

**CONFIDENTIALITY/ANONYMITY**
The data collected will not contain any personal information about participants except GPS measured location, date of birth and gender. No one will link the data participants provide to any identifying information (e.g., name, email). It is expected that data will be used to write a paper for inclusion in my thesis and possible journal publication.

**FOR FURTHER INFORMATION**
Further information regarding the background, methods and final results of the study are available on request. Please contact:

Matthew Pearce
Room 2.15
The Institute for Sport, Physical Education and Health Sciences
University of Edinburgh
m.pearce@sms.ed.ac.uk

## PARTICIPANT INFORMED CONSENT

**PROJECT TITLE**
Indoors or Outdoors? Examining the Use of GPS Data to Differentiate Physical Activity Location

**PROJECT SUMMARY**
Accurate, objective measurement tools are important for accurately describing the amount and context of physical activity. Using the output from GPS receivers, time outside can be estimated. At present the data processing steps required to produce an estimate of time outside are unclear. As such, the estimate of time outside using GPS needs to be compared to a known criterion standard, in this case, direct observation of the participant.

Adult participants will be asked to wear a Qstarz GPS data logger to measure position every five seconds. Participant location will also be directly observed by an investigator for 2-3 hours on at least one day.

**DECLARATION**
By signing below, you are agreeing that: (1) you have read and understood the Participant Information Sheet, (2) questions about your participation in this study have been answered satisfactorily, (3) you are aware of the potential risks (if any), and (4) you are taking part in this research study voluntarily (without coercion).

________________________________
Participant's Name (Printed)

________________________________ ________________________________
Participant's signature Date

________________________________ ________________________________
Name of person obtaining consent (Printed) Signature of person obtaining consent

# Appendix C

Materials for Chapter Seven:

1. Letter to parents including informed consent.
2. Information sheet for participants.
3. Physical activity diary.
4. Instruction sheet for participants.

The Institute for Sport, Physical Education and Health Sciences
The Moray House School of Education
The University of Edinburgh
St Leonard's Land
Holyrood Road
Edinburgh EH8 8AQ
Telephone 0131 651 9784
M.Pearce@sms.ed.ac.uk

**Dear Parent/Guardian,**

I am writing to inform you that your child's school has agreed to participate in my PhD project being conducted at The University of Edinburgh. In addition to contributing towards the success of the study, I feel that it will be an interesting, educational and enriching experience for them.

**About the study**
Physical activity is very important for the health of children, however many children are inactive. This study aims to investigate how much physical activity children accumulate in different contexts (e.g. at school, playing, sports lessons) and explore related factors. The study is approved by City of Edinburgh Council and The Moray House School of Education Ethics Committee.

**What will my child have to do?**
Your child will be asked to wear two electronic devices during waking hours for seven days (including the weekend). Device 1 is an accelerometer which measures movement and allows estimation of physical activity. Device 2 is a GPS receiver which records location every ten seconds. ***All recorded data are anonymised and will not be available until after the devices are returned, i.e. there is no 'live' tracking of the participants***. Both devices are small, lightweight and worn around the waist on an elasticated belt.

Children will be asked to complete a very short questionnaire and record any organised physical activity they engage in using a diary. Height and weight measurements will be taken at an introductory session at school allowing calculation of Body Mass Index (BMI). All data will be anonymised and will only available to the researcher.

Children will be asked to wear the devices during all waking hours, taking them off at night and putting them back on in the morning. Participants will be provided with a USB charger to charge the GPS receiver overnight.

**What will I have to do?**
The study has been designed to place very little burden upon parents; however some encouragement to wear the monitors and reminders to charge the GPS overnight would be appreciated.

**What will happen to the data?**
All information will be anonymised and held securely at the University of Edinburgh. Personal data will not be shared with third parties.

**What happens next?**
If you are happy for your child to take part in the study, please return the informed consent slip below by **next Monday.** Participating children will be instructed how to wear and charge the devices and given information packs including their activity diaries on Monday next week. Verbal consent with your child will be agreed on the first day of the study. Your child will be free to withdraw at any stage.

I very much hope your child will participate in this study. If you have any questions please feel free to contact me using the details above.

Yours Sincerely

**Matthew Pearce**
PhD student
The University of Edinburgh
Supervisors: Dr. Tony Turner, Dr. Pete Allison, Dr. David Saunders

**INFORMED CONSENT**
By signing below, you are agreeing that: (1) you and your child have read and understood the above information and are happy to take part, (2) any questions about participation in this study have been answered satisfactorily, (3) you are aware of the potential risks (if any), and (4) you are happy that you child is taking part in this research study voluntarily.

________________________________
Child's Name (Printed)

________________________________ ________________________________
Parent's signature Date

Please return this form to school **by next Monday** if you are happy for your child to be involved in the study. Alternatively email Matthew Pearce at M.Pearce@sms.ed.ac.uk

# Physical Activity Study

THE UNIVERSITY *of* EDINBURGH

The University of Edinburgh is doing an experiment to test how much physical activity children do, and where they do it. Physical activity includes lots of different things, such as playing in the park, walking home from school, and even doing chores at home. Your school is one of only four in Edinburgh to be taking part, and we would very much like you to be involved.

**What do I have to do?**

There are two parts to the experiment:

***Part 1*** We will ask you to wear a special belt with two pieces of equipment attached to it. This equipment tells us how much activity you do and where you do it. We need you to wear the belt all day for 7 days including the weekend. This is not a competition; we are only interested in your normal pattern of activity. You can take the belt off when you go to sleep at night and when you have bath or shower. *See the next page for information about the equipment you will be using*. We also need to take some measurements about your weight and height.

***Part 2*** You will also be asked to write down the times of any organised activity you do after school or at the weekend in a diary that we give you. For example we need you to write down if you go to football/rugby training, dance classes, Scouts or other clubs normally organised by adults.

**IMPORTANT**

No one will be able to identify you from the information you give us, and we can only use data from the equipment belt ***AFTER*** you give it back (we can't spy on you). Data will be kept securely at the University. You do not have to take part in the experiment and you can leave the study at any time without having to give a reason.

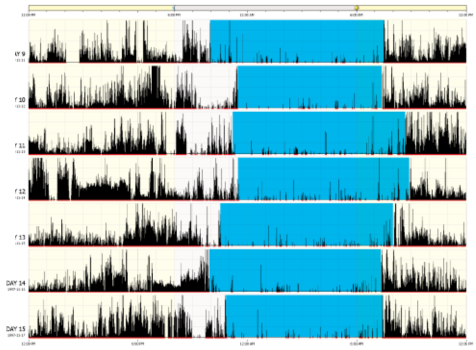
# Equipment

The belt we give you has two pieces of equipment on it: an accelerometer and a GPS receiver.

**Accelerometer**

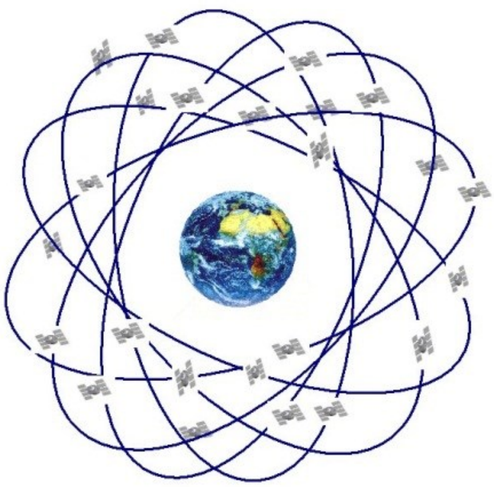
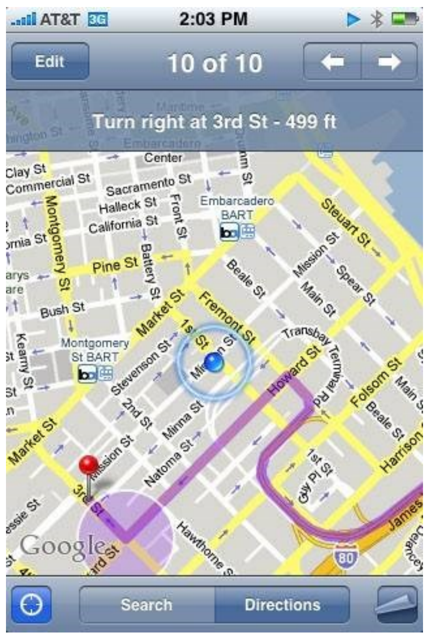
An accelerometer is a piece of equipment that measures how much activity you do. Accelerometers measure movement and are used in Nintendo and PlayStation controllers.

The accelerometer on your belt is called an ActiGraph and is cutting edge technology. It is very small and light. When you give the ActiGraph back to us, we can download the information to create graphs telling us when you were the most active.



**GPS receiver**

GPS stands for Global Positioning System. The GPS was set up by the USA and uses 24 satellites which orbit the Earth constantly. The receiver on your belt collects signals from the satellites in Space to record your location. Many mobile phones have GPS receivers inside. Google Maps uses GPS to show you where you are.

**ACTIVITY DIARY**

Please record the times of organised/structured activities you take part in each day, such as:

- Sports training or matches (including school sport)
- Swimming or diving lessons
- Clubs such as Scouts
- Dance classes
- Any other organised clubs or training

Tuesday

| Name of activity | Start time | End time |
|---|---|---|
| *e.g Football match* | *3:30pm* | *5:00pm* |
| | | |
| | | |
| | | |

Wednesday

| Name of activity | Start time | End time |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

Thursday

| Name of activity | Start time | End time |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

Friday

| Name of activity | Start time | End time |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

Saturday

| | | |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

Sunday

| Name of activity | Start time | End time |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

Monday

| Name of activity | Start time | End time |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

# Please return this completed diary with your equipment next Tuesday

## Please complete this diary with a parent/guardian

| | | | |
|---|---|---|---|
| Name | | | |
| School | | | |
| Gender | Male □ | | Female □ |
| Date of birth | Day | Month | Year |
| Ethnicity | White □<br>Mixed □<br>Chinese □ | | Asian or Asian British □<br>Black or Black British □<br>Other : |
| Address | House/flat number<br><br>Street name<br><br>Town<br><br>Post code | | |

# Equipment instructions

It would be great if you could wear the belt every day for next 7 days, including Saturday and Sunday. The aim is to collect as many hours of information as possible. This means you need to put the belt on as soon as you get up in the morning and take it off before you go to bed.

It is important to remember that this is **not a competition**; we are only interested in your normal activity. **The most important thing is that you wear the belt for as much time as possible.**

**REMEMBER:** All the information is private and no one except the researcher will see it.

**WEARING THE BELT**

The belt should be worn around your waist with the clip at the front.
The **RED** box should be on your right hand side.
The **BLACK** box can go anywhere on the belt.

The equipment is **NOT WATERPROOF**, so don't wear it in the bath or shower or if you go swimming.

**CHARGING THE BLACK GPS BOX**

The black GPS receiver needs to be charged each night or the battery will run out, meaning it can't record any data.

Please charge the black GPS box with the USB charger we have given you. You don't need to take the GPS off the belt; there is a hole in the side of the GPS holder for the charging lead.

**RETURNING THE EQUIPMENT**

Next week, the researcher will come back to school to collect the equipment and your activity diary. Please bring the equipment and diary with you on this day.

***Thank you for taking part, if you encounter any problems please contact Matthew Pearce at M.Pearce@sms.ed.ac.uk***